AGRONOMY SEMINAR
305 DAVENPORT HALL

ОЧВОВЕДЕНИЕ

SOVIET SOIL SCIENCE

4

APRIL 1961

A TRANSLATION
OF POCHVOVEDENIYE

★

AMERICAN INSTITUTE
OF BIOLOGICAL SCIENCES
2000 P STREET, N.W.
WASHINGTON 6, D. C.

SOVIET SOIL SCIENCE

A. P. MAZURAK, *Editor*
Department of Agronomy, University of Nebraska

Patricia Haley
Assistant Editor

American Institute of Biological Sciences

Officers
Tracy M. Sonneborn, *President*
Bernard S. Meyer, *Vice-President*
F. P. Cullinan, *Secretary-Treasurer*

Executive Director
Hiden T. Cox

Chairman,
Committee on Translations
Fred R. Cagle

Director of Publications
Francis C. Harwood

Governing Board
George Beadle
Albert P. Blair
Fred R. Cagle
David E. Davis
E. L. Dulaney
Wallace O. Fenn
Clifford Grobstein
A. M. Guhl
Freeman S. Howlett
Paul J. Kramer
W. Gardner Lynn
Dorothy Matala
George L. McNew
Bernard S. Meyer
Fred S. Orcutt
F. W. Poos
Roger D. Reid
Reed C. Rollins
William Steere
John A. Stevenson
Karl A. Stiles
Carl P. Swanson
Kenneth Thimann
Arthur C. Walton
Richard G. Zweifel

The translation and publication of this and other Russian language biological journals and monographs is a project of the American Institute of Biological Sciences. This project is supported by grants from the National Science Foundation. Each publication is a cover-to-cover translation of its Soviet counterpart and the contents are only those of the original authors.

Pochvovedeniye in English translation bears the Soviet issue numbers. The Soviet journal carries no volume numbers. Translation begins with Number 1, the January 1958 issue. It is published in the same number of issues per year as the original Soviet journals: 12 issues.

translated and produced by
ROYER & ROGER, INC.
INTERNATIONAL DIVISION

Subscription Prices:

$40.00 per year, individuals and industrial libraries
20.00 per year, university and non-profit libraries
3.00 additional to each price for foreign orders
4.50 each, single copies

Order from:

American Institute of Biological Sciences
2000 P Street, N.W., Washington 6, D.C.

© 1961 American Institute of Biological Sciences

SOVIET SOIL SCIENCE

A translation of the monthly journal—POCHVOVEDENIYE—
a publication of the V. V. Dokuchayev Institute of Soil Science,
Academy of Sciences, USSR. A journal founded in 1899.

Pochvovedeniye Editorial Board: I. V. Tyurin (editor-in-chief), I. N. Antipov-Karatayev, N. I. Gorbunov, K. P. Gorshenin. A. A. Zavalishin, V. N. Zavaritskii, S. V. Zonn (assistant editor), O. K. Kedrov-Zikhman, V. M. Klechkovskii, V. A. Kovda, M. M. Kononova (assistant editor), Ya. V. Peive, I. I. Sinyagin, A. V. Sokolov

---

No. 4: April 1961 Translation printed: March 1962

CONTENTS

	Page	Russian Page
METHOD OF COMPILING LARGE-SCALE SOIL AGRICULTURAL CHEMICAL MAPS FOR FERTILIZER APPLICATION, by I. G. Vazhenin, Ye. T. Muzychkin, Z. A. Prokhorova, and T. N. Aleshina	363	1
MOST IMPORTANT RESULTS OF TEN YEARS' STUDY BY THE DZHANYBEK STATION, ACADEMY OF SCIENCES, USSR, by A. A. Rode	375	14
AGRICULTURAL CHEMICAL CHARACTERISTICS OF SOILS OF THE MOSCOW RIVER FLOOD PLAIN (BOTTOM LAND), by L. I. Korableva	387	30
DESALINIZATION CONDITIONS OF MEADOW SOILS AT THE MIDDLE COURSE OF THE AMU DAR'YA RIVER, by I. S. Rabochev	395	40
HEAT OF WETTING AND CONTENT OF TIGHTLY BOUND WATER IN CLAY MATERIALS, by N. P. Zatenatskaya	402	47
DATA ON THE DYNAMICS OF SOIL-FORMATION PROCESSES IN SOLODIZED SOILS OF THE ALTAYSKIY KRAY, by T. V. Tursina	410	56
SPECIFIC RESISTANCE OF GREY FOREST SOILS DURING PLOWING IN THE PAKHOMOVO SOVKHOZ, TUL'SKAYA OBLAST', by P. U. Bakhtin and V. I. Volotskaya	420	68
COBALT ABSORPTION BY PLANTS IN RELATION TO THE HUMUS CONTENT IN SOIL, by N. V. Kulikov	428	78
MANGANESE-IRON CONCRETIONS IN SOILS OF THE SUIFENHO-KHANKA LOWLAND, by V. I. Roslikova	431	82
SLIGHTLY SALINIZED SOILS OF MICROHILLOCKS AMONG LAKE SOLONCHAKS OF INNER MONGOLIA, CHINESE PEOPLE'S REPUBLIC, by B. A. Zimovets	438	91

METHODS

	Page	Russian Page
EXTRACTION OF FREE (NONSILICATE) IRON AND ALUMINUM FROM SOILS AND CLAYS, by I. G. Tsyurupa	443	96
USE OF ION EXCHANGE RESINS FOR THE QUALITATIVE DETERMINATION OF MICROELEMENTS, by I. K. Tsitovich	454	107

	Page	Russian Page
NITROGEN-FIXING BACTERIA IN THE RED EARTH SOILS OF GEORGIA, by N. A. Daraseliya	459	111
TRANSFORMATION ON UREA IN THE SOIL, by A. F. Kalinevich	463	114
BIBLIOGRAPHY	467	118

METHOD OF COMPILING LARGE-SCALE SOIL AGRICULTURAL CHEMICAL MAPS FOR FERTILIZER APPLICATION

. G. VAZHENIN, YE. T. MUZYCHKIN, Z. A. PROKHOROVA, and T. N. ALESHINA, V. V. Doku-
hayev Soil Institute, Academy of Sciences, USSR

Compiling large-scale chemical maps is one f the most important factors in the chemical control of the correct and efficient utilization of oil fertility and of fertilizers added into the oil.

During recent years, in association with the great amount of work on large-scale soil mapping, the compilation of these maps has attained wide significance; however, we cannot regard he level of this investigation as satisfactory in he qualitative sense. The maps being compiled during soil investigations are schematic, ince they are prepared on the basis of a very imited number of analyses (one analysis every 0-50 hectares or more). Consequently, proiles of chemical indices on the maps usually epeat the profiles of soil types or groups. These schematic soil chemical maps may serve merely as general recommendations for ferilizer application in farming, but they are not he basis for proper placement of fertilizers on otation fields and crops. To utilize efficiently oils and fertilizers among farms, detailed hemical soil maps should be compiled which xpress the chemical characteristics of individual crop rotation fields and even of parts of ields, providing the history of land utilization tenure) on them differs.

Despite a long-standing history of agriculturl chemical research in the USSR and large-cale mapping of soils (5), soil mapping proedures are still entirely inadequate. The ollowing problems, for example, have not been tudied.

1. How detailed soil chemical maps should e for various soil zones and how often soils hould be sampled for chemical analyses, which will be sufficiently detailed and at the same ime economically justifiable.

2. General organizational principles of soil hemical investigations: selection, preparation, nd formulation of cartographic data; breakdown f soil fields into smaller (mapped) strips; soil ampling procedures (of mixed and individual samples), a system for recording results during field study and maintaining explanatory notes to the cartograms.

3. Structure, system, and organization of analytical research in laboratories; devising efficient methods for chemical analyses which are sufficiently accurate, rapid, and inexpensive.

To resolve these problems, systematic studies have been made in 1958-1959 at 6 farms located on various soil groups:

1. On sod-podzolic, medium, and coarse clay loams formed on fine clay loams (the Mikheykovskiy sovkhoz, Yartsevskiy rayon, Smolenskaya oblast', and the experimental farm of the Department of Biological Sciences, Academy of Sciences, USSR, "Snegiri", Moskovskaya Oblast').

2. On medium clay loam gray forest soils, formed on fine clay loams, (sovkhoz "Pakhomovo", Tul'skaya Oblast' and the Uzunovskaya Experimental Station, Moskovskaya Oblast').

3. On medium clay loam chernozems of the forest steppe (kolkhoz imeni Vladimira Il'icha, Serebryanoprudskiy rayon, Moskovskaya Oblast', and the sovkhoz "Serebryanyye Prudy", Serebryanoprudskiy rayon).

Principal objectives of our studies were: 1) to study the relationship between the content of available forms of nitrogen, phosphorus, and potassium in soils and their genesis, cultivation state and land use; 2) to develop the spatial heterogeneity (variegation) in the content of available forms of nitrogen, phosphorus, and potassium in soils; 3) to establish conformities between soil contours and chemical indices contours; 4) to compare results of studies on mixed and individual

---

[1] "Report at the All-Union Conference on the site uality and agricultural chemical characteristics of oils of the USSR, Moscow, December, 1959."

[2] A systematic study of agricultural chemical divisions (?), was a part of the complex studies being made by laboratories of the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR. The laboratory concerned with large-scale mapping conducted at the same time a comparative study of various methods of large-scale soil mapping. A scale of 1:10,000 was adopted as the basic work scale for the soil maps and cartograms being compiled.

Table 1

Comparative chemical characteristics of various soil groups

Soil	Fertilizer application on farms							
	Extensive use				Intensive use			
	pH	N	P_2O_5	K_2O	pH	N	P_2O_5	K_2O
Sod-podzolic	4,5—5,5	5—7	7—13	10—15	4,5—6,0	5—6	12—15	12—15
Gray forest	5,0—5,5	5—7	3— 6	10—13	5,0—5,5	5—6	8—10	15—20
Chernozem	5,5—6,0	7—8	3— 5[a]	11—16	5,5—6,0	5—7	5— 7[a]	17—20

[a] Easily soluble phosphates have been determined by the Chirikov method.

Note: Comma represents decimal point.

samples; and 5) to determine the minimum soil samples sufficient to compile large-scale soil chemical maps.

To solve these problems, specific size (250-600 ha) land areas typical in the farm and soil sense were divided off at each of the farms. The farms studied in 1959 ("Snegiri", Uzunovo, and sovkhoz "Serebryanyye Prudy") were characterized by a higher agricultural level (better soil cultivation, presence of crop rotation, high fertilizer rates, and proper fertilizer utilization, crop varieties, better crop management, smaller harvest losses, etc.). Consequently, basic agricultural crop yields at these farms were 2 to 3 times higher than on farms of the first group (Mikheykovskiy sovkhoz, "Pakhomovo" sovkhoz, and kolkhoz imeni Vladimira Il'icha).

An agricultural chemical study of soils was made on the following land use: plowed fields, abandoned land (pasture or hay field), and forest. To study the plowland, strips of varying degrees of cultivation—high, average, and low—were selected. The plowlands were separated according to the degree of cultivation based on a study of the history of the fields and of soil productivity: "the highly-cultivated soils" of house and garden crop rotations are the most fertile; the "low cultivated" soils are soils of strips furthest removed from settlements and only slightly fertilized and, consequently, least fertile. At each farm the principal land areas were assigned to the "medium cultivated soils" which, by their properties, assumed a middle position.

To solve the foregoing problems, we proceeded by mapping these soils by hectare, i.e., beginning with the greatest soil sampling density. The results of this mapping have been compared with the mapping results when 1 soil sample is taken every 4-5, 9-10, 15-16 and 20-25 hectares. Soil samples were taken before adding fertilizers during the spring and summer period, first, from fields covered with winter and early spring grain, and then, towards the end, from black fallow and fields used for row crops.

Based on the analytical data obtained, soil chemical maps were compiled, and by use of statistics, appropriate calculations were made, reflecting the chemical characteristics of these soils in connection with their genesis, cultivation level, land tenure history, and land use.

Table 1 presents chemical characteristics of plowed soils on farms of comparatively low agricultural practices and on farms having a higher farming system. We see from this table that from the average chemical indicators (nitrogen, phosphorus, and potassium), all plowed soils—the sod podzolic, gray forest, and chernozems—are similar. By farm types the average chemical characteristics of soils were also closely alike.

The reason for the comparative similarity of various plowed soil groups in nitrogen, phosphorous, and potassium content is explained, obviously, by the relative similarity in agricultural practices employed in these zones. Consequently, group differences in a plowed soil layer are considerably graded.

It seems inconceivable at first glance that hydrolyzed nitrogen content was somewhat less in the second group of farms where manure and mineral fertilizers were systematically applied, while the content of phosphorus and potassium was approximately the same as in the soils of farms of the first group. As we have already pointed out, all agricultural crop yields on farms of the second group were 2 to 3 times higher. Since moderate amounts of fertilizer were also used on these farms, and there was a greater removal by crops of nutrient elements, no substantial accumulation of phosphorus and potassium (on an average for the farm soils) took place, and even the nitrogen content decreased.

We see from Table 2 that of all the soil groups the soils of abandoned lands used ordinarily as pastures and hay fields, are most deficient in phosphorus and potassium. Systematic removal of nutrients by plants and a practically total absence of fertilizer have impoverished these soils and made them of low productive capacity.

The plowed soils, as compared with soils beneath the forest, were somewhat more deficient in hydrolyzable nitrogen. This may be the result of the fact that plowlands have been exhausted of available forms of nitrogen substances and that in the upper soil layer beneath the forest a vigorous mineralization of plant litter takes place in the summer, which results in an increas in content of hydrolyzable nitrogen (soil samples in the forest were taken in June). Sod-podzolic

Table 2

Content of available forms of nitrogen, phosphorus, and potassium in various soils (farms on low agricultural level)[a]

Soil	N (after Tyurin and Kononova)			P_2O_5 (after Kirsanov)			K_2O (after Maslova)		
	$M \pm m$	σ	K	$M \pm m$	σ	K	$M \pm m$	σ	K
Sod-podzolic soils, Mikheykovskiy sovkhoz, Smolenskaya Oblast'									
Sod weakly-podzolic	4,5±0,5	0,8	18	10,4±3,5	7,5	72	10,1±1,2	2,8	28
Sod moderately podzolic	7,6±0,7	1,3	17	6,8±1,7	4,6	67	11,4±1,0	3,2	28
Sod weakly- and moderately podzolic	6,8±0,3	0,8	12	9,1±0,9	4,9	54	13,3±1,2	3,4	25
Sod moderately- and weakly podzolic	6,0±0,3	1,1	18	13,1±2,2	9,1	69	13,9±1,3	6,0	43
Sod moderately-weakly-and strongly podzolic (complex)	6,6±0,3	0,8	12	9,5±0,9	3,0	32	16,3±1,3	4,4	27
Sod moderately podzolic (mixed forest)	8,6±1,2	2,8	32	5,8±0,7	2,3	40	9,8±0,6	1,8	18
Sod moderately podzolic (abandoned land)	—	—	—	2,2±0,3	1,5	53	9,4±0,6	3,2	34
Gray forest soils, "Pakhomovo" sovkhoz, Tul'skaya Oblast'									
Light-gray podzolic	5,6±0,4	1,3	22	4,6±0,3	2,4	52	10,3±0,3	2 2	21
Gray podzolic	7,2±0,5	1,5	20	6,3±0,8	3,3	45	23,7±3,8	15,4	65
Light-gray gley	6,7±0,7	1,9	29	4,7±0,5	3,1	66	12,3±0,6	3,8	31
Gray meadow	5,5±0,3	0,9	16	4,1±0,4	1,8	43	12,3±0,8	2,8	23
Light-gray strongly- and moderately podzolic (complex)	5,4±0,5	2,2	41	3,3±0,2	1,2	37	13,3±0,4	3,4	25
Light-gray strongly- and moderately-podzolic (complex, under forest)	8,2±0,6	1,4	15	4,1±0,4	2,3	55	21,6±0,1	0,5	3
Light-gray podzolic, abandoned land	—	—	—	1,1±0,3	0,6	53	8,6±0,3	0,8	9
Chernozems and dark gray forest-steppe soils, kolkhoz imeni Vladimira Il'icha, Moskovskaya Oblast'[b]									
Podzolized chernozems	7,2±0,5	1,8	25	4,2±0,1	1,3	30	16,9±0,2	1,8	11
Leached chernozems	7,2±0,5	0,9	12	3,1±0,2	1,2	39	15,9±0,2	1,0	6
Meadow chernozems	7,6±0,2	0,3	4	4,7±0,1	0,8	17	16,5±0,5	3,2	20
Chernozem-meadow soils	7,6±0,3	0,9	12	3,2±0,1	1,4	43	10,9±0,5	3,3	30
Dark gray forest soils (plowland	—	—	—	2,4±0,1	0,9	38	13,1±0,3	2,2	16
Podzolized chernozems (oak forest)	9,5±0,8	1,3	14	3,3±0,2	0,8	24	18,0±0,6	2,4	13
Meadow-chernozem (aband. land)	—	—	—	2,6±0,1	0,5	18	9,8±0,3	1,1	11

[a] Symbols in the table are: M—arithmetic mean for n treatments; σ—standard deviation = $= \pm\sqrt{\frac{\varepsilon p\alpha^2}{n-1}}$; m—standard error $= \frac{\sigma}{\sqrt{n}}$: K—variation coefficient $= \frac{\sigma \cdot 100}{M}$.

[b] P_2O_5 in chernozems determined by Chirikov.

Note: Comma represents decimal point.

oils of plowlands are richer in available (acid-oluble) phosphorus and even exchangeable po-assium than are soils beneath the forest and andoned land. Compared with these soils e arable chernozems and gray forest soils are ill more deficient in potassium, while the connt of phosphorus is approximately the same. hese differences, it seems, are explained by ss fertilizer applied on farms located on chernozems and gray forest soils. As a result of the extensive agricultural utilization of these soils the total effective fertility level (with respect to nutrients) has been lowered somewhat.

From data in Table 2 we see that for all soil groups the variation of indices within each soil group is considerably greater than the differences among arithmetic means which

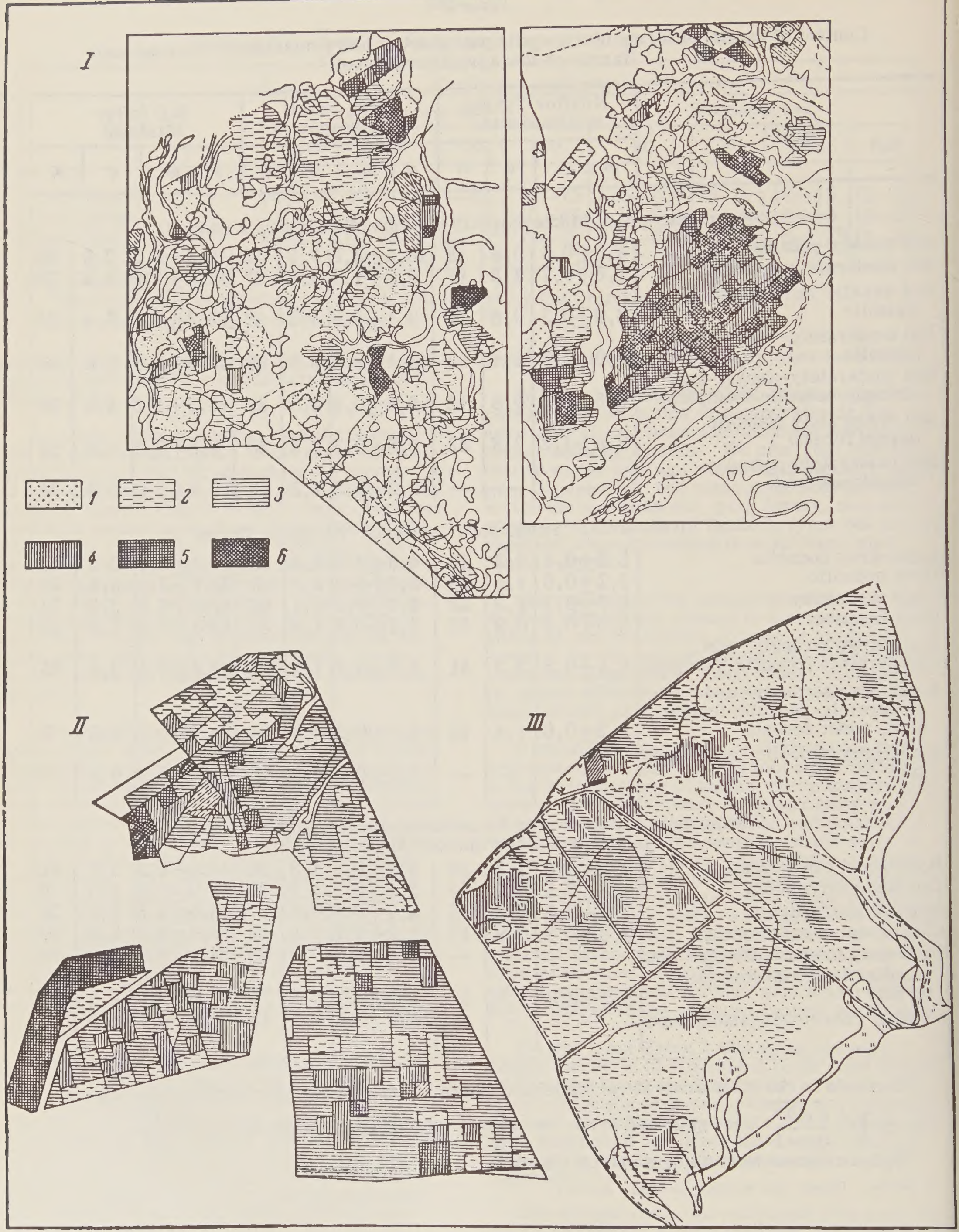


Fig. 1. - Maps with contents of available phosphates in various soils. I - sod-podzolic soils (Mikheykovskiy sovkhoz); II - gray forest soils ("Pakhomovo" sovkhoz); III - chernozem soils (kolkhoz imeni Vladimira Il'icha). 1 - less than 5 mg; 2 - 5 - 10; 3 - 10 - 15; 4 - 15 - 20; 5 - 20 - 30 mg; 6 - more than 30 mg P_2O_5 per 100 g of soil.

characterize these soil groups. The decrease in content of P_2O_5 observed in sod moderately-podzolic soil and, conversely, the increase in the content of nitrogen, phosphorus, and potassiu

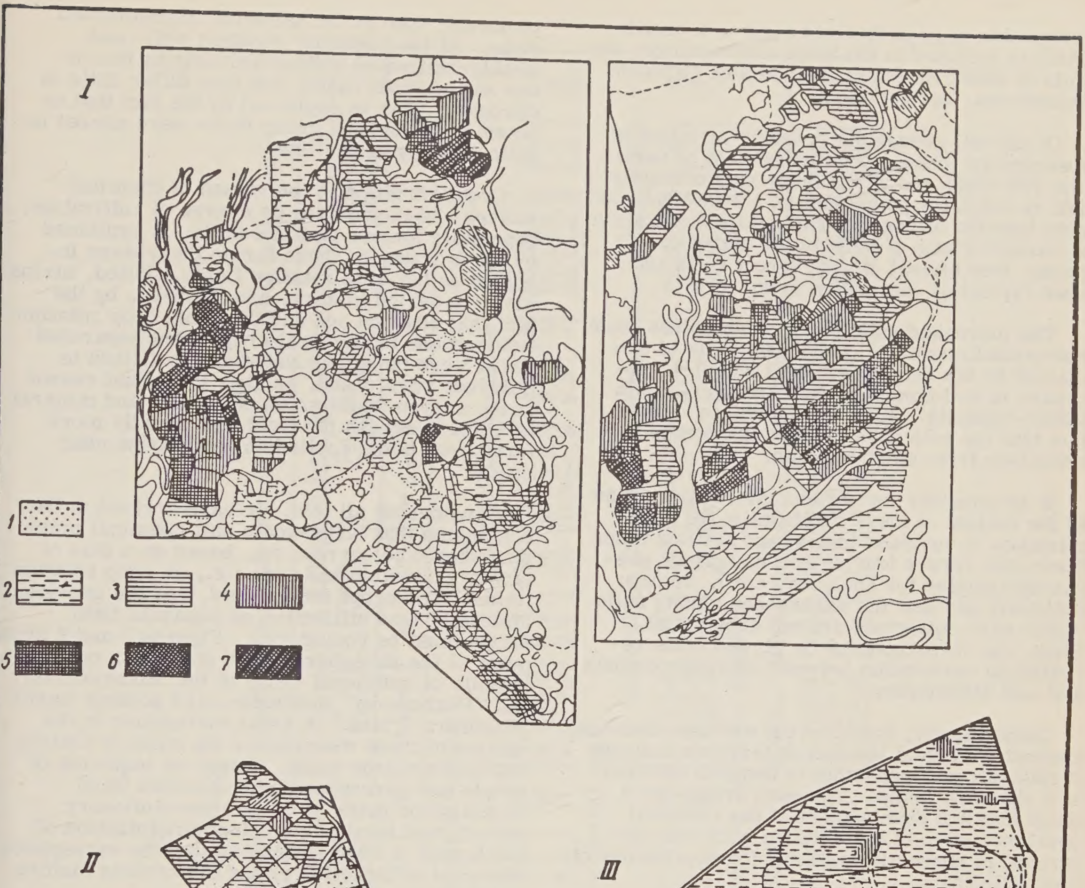


Fig. 2. - Maps with contents of exchangeable potassium in various soils. See Figure 1 for explanations of I, II, and III. 1 - less than 10 mg; 2 - 10 - 15; 3 - 15 - 20; 4 - 20 - 30; 5 - 30 - 40; 6 - 40 - 50; 7 - more than 50 mg per 100 g of soil.

n gray podzolized soil is explained not by soil genetic) characteristics but by agricultural conditions. Thus, associated with moderately-podzolic soils (during computation) is a profile used on the farm as a hay field and these soils are strongly impoverished in phosphates;

assigned to gray podzolized soils is a profile which is included in the farm crop rotation, the soils of which have a high content of nitrogen, phosphorus, and potassium.

Of all soil groups the greatest variation is observed for phosphorus (coefficient of variation 30%-80%); the variation is approximately half as much for potassium (K = 20%-35%) and even less for nitrogen. The greatest variation is characteristic of soils of the sod-podzolic group, less typical of gray forest soils and least typical of chernozem soils.

The increased stability of mean values from sod-podzolic soils to chernozem soils is explained by the decrease in soil complex, increase in soil humus content and increase in buffer-capacity. Also of importance is the fact that the role of fertilizers decreases relatively from north to south.

If we consider the natural microvariegation in the content of these nutrients in the soil, mistakes in analyses (mass) and several other inevitable errors (during soil sampling, preparing samples for analyses, etc.), we can definitely say that the differences among soils within each soil group are not substantial. Thus, our investigations on plowed soils revealed no correlation between nutrient contents and soil differences.

Consequently, based on the average chemical characteristics of the soil differences mapped, it does not seem possible to compile detailed soil chemical maps. The need arises for a more detailed development of the chemical characteristics of soils within each soil difference in connection with the former history of land utilization.

Effect of Soil Cultivation Level on the Variation of Chemical Indices

Grouping of soils by degree of cultivation was based, as we have already pointed out, on the history of the soils and their productive capacity—agricultural crop yields for several previous years. When grouping soils by degree of cultivation, variation in the values of the elements studied is significant but is somewhat less than when grouping soils by soil groups (Table 3). Variation in phosphorus—the element which best expresses the degree of soil cultivation was particularly reduced.

The differences in degree of cultivation are best of all expressed for sod-podzolic soils, somewhat less expressed for gray forest soils, and even less expressed for chernozem soils; consequently, the differences decrease with the intensiveness of fertilizer application. For this same reason the differences in degree of cultivation are more strongly expressed on farms having a lower agricultural level, where fertilizers are applied to fields in an extremely uneven manner and mostly concentrated on limited areas.

In the sod-podzolic well-cultivated soils of the first group of farms (the Mikheykovskiy sovkhoz), the phosphorus content and potassium content are six and three times greater, respectively, than in the same but impoverished soils. At the "Snegiri" sovkhoz well- and weakly-cultivated soils differ only by two to one and one half times, but they differ little in nitrogen. This is explained by the fact that on farms of the second group there were almost no soils entirely unfertilized.

Great variation in the values of chemical indices and in grouping by degree of cultivation, especially for sod podzolic soils, is explained by the fact that on these farms there were included on the crop rotation fields allotted, strips having a varied history, and likewise, by the fact that often on one and the same crop rotation field not one but several crops were separated which were being cultivated and fertilized in different ways. And, another important reason is the uneven distribution of organic and mineral fertilizers across the field with usually more fertilizers being applied on field strips near roads.

Considering all this, we have arrived at the conclusion that large-scale soil chemical mapping should be carried out, based on a plan of land organization and use, i.e., on crop rotation fields. The crops on the field, and the previous history of land utilization on separate field strips must be considered. Figures 1 and 2 show maps of the phosphorous and potassium content in soils of individual fields of the Mikheykovskiy and "Pakhomovo" sovkhozes, and kolkhoz imeni Vladimira Il'icha. A great variegation in the content of these elements in the soils is clearly expressed on the maps. Based on inquiries of people and corresponding documents (land organization plans of the pre-revolutionary period, and local plans before organization of kolkhozes) it was established that the variegation observed is directly related to previous history of land utilization.

The greatest variegation in phosphorus and potassium content is noted on sod-podzolic soils. Here variations are expressed in 4 to 6 groups, from soils totally lacking in phosphates and potassium to soils of abundant phosphate and potassium saturation. For example, on sovkhoz fields situated east of the village of Mikheykovskoye, the average phosphate content is 20-30 mg P_2O_5 and potassium 20-25 mg K_2O per 100 g of soil. From the history of the lands of this sovkhoz, we know that these fields were subjected to greater fertilization and were more fertile even under kolkhoz land tenure. And, at present, these fields, spacious and conveniently located to roads and livestock farms, receive comparatively large amounts of mineral fertilizers and manure. At the same time, numerous distant fields situated northeast of the village are very severely lacking in phosphorus and potassium.

A comparatively lesser, but still significant variegation is observed in the gray forest soils (the "Pakhomovo" sovkhoz). On a four crop rotation field, the content of P_2O_5, according to Kirsanov, is 15-20 mg, while on certain strips the content of P_2O_5 is 30-40 mg. On the fields far removed from the village the total P_2O_5 content is only 2-3 mg per 100 g of soil. The content of exchangeable potassium in the soil for a farm crop rotation is 20-30 mg, while on distant fields employing field rotation K_2O content is 5-10 mg per 100 g of soil. Even on chernozem soils

Table 3

Content of available forms of nitrogen, phosphorus and potassium in various soils in connection with degree of cultivation

Degree of cultivation	Farms on low agricultural level									Farms on a higher agricultural level								
	N (after Tyurin and Kononova)			P_2O_5 (after Kirsanov)			K_2O (after Maslova)			N (after Tyurin and Kononova)			P_2O_5 (after Kirsanov)			K_2O (after Maslova)		
	$M \pm m$	σ	K	$M \pm m$	σ	K	$M \pm m$	σ	K	$M \pm m$	σ	K	$M \pm m$	σ	K	$M \pm m$	σ	K
	Sod-podzolic soils																	
	Mikheykovskiy sovkhoz, Smolenskaya Oblast'									"Snegiri", Moskovskaya Oblast'								
High	7,6±0,5	1,2	16	24,2±1,9	5,6	24	20,4±1,9	5,7	28	6,8±0,4	1,7	25	21,5±1,6	11,9	55	15,0±0,5	4,0	27
Average	7,0±0,4	1,3	19	12,6±1,6	3,6	28	12,2±1,1	3,1	26	6.5±0,2	0,9	14	18,0±1,3	9,6	53	10,5±0,7	5,4	51
Low	6,0±0,4	1,6	26	4,3±0,5	1,3	30	7,7±0,3	0,8	11	5,1±0,8	2,6	52	12,8±1,5	9,3	73	10,7±0,3	2,2	20
	Gray forest soils																	
	"Pakhomovo" sovkhoz, Tul'skaya Oblast'									Uzunovskaya Experimental Station, Moskovskaya Oblast'								
High	7,2±0,5	1,2	17	13,5±2,1	9,3	69	24,5±3,2	14,4	59	5,6±0,2	0,5	10	14,0±0,9	2,9	23	22,8±0,6	1,8	8
Average	6,8±0,8	1,9	30	4,4±0,4	1,8	42	12,3±0,6	2,7	21	5,7±0,4	1,2	21	9,0±0,7	1,8	20	16,6±0,4	2,1	12
Low	5,3±0,4	0,9	17	3,2±0,3	1,5	29	8,4±0,4	1,8	21	5,3±0,3	1,0	21	6,2±0,4	2,1	34	15,0±0,3	1,5	7
	Chernozem soils of the forest steppe																	
	Kolkhoz imeni Vladimira Il'icha, Moskovskaya Oblast'									Sovkhoz "Serebryanyye Prudy", Moskovskaya (Ryazanskaya) Oblast'								
High	9,2±0,2	0,4	5	9,8±1,5	2,4	24	37,8±4,6	16,0	45	5,7±0,9	2,2	38	7,2±0,4	1,7	23	17,6±0,2	1,8	10
Average	7,2±0,5	0,9	13	4,1±0,0	0,14	4	15,9±0,4	4,0	26	4,5±0,1	0,5	12	6,0±0,1	0,3	4	18,0±0,5	3,1	17
Low	7,6±0,3	0,9	12	2,8±0,2	1,5	54	10,7±0,4	3,0	29	4,4±0,3	0,6	13	4,0±0,1	0,8	20	22,6±1,4	5,2	23

Note: Comma represents decimal point.

Table 4

Distribution of soil areas by content of available forms of phosphates and potassium, % of total area

P_2O_5						K_2O					
Area of mapped square in ha											
P_2O_5 in mg per 100 g of soil	1	4	9	16	25	K_2O in mg per 100 g of soil	1	4	9	16	25
Distribution of soil groups, % of total area											
Sod-podzolic soils, Mikheykovskiy sovkhoz											
<5	27	20	17	10	—	10	31	30	30	16	10
5—10	33	38	31	42	56	10—15	38	36	33	44	50
10—15	11	15	24	16	8	15—20	16	20	26	32	40
15—20	9	15	17	24	32	20—30	11	12	12	8	—
>20	15	12	10	8	4	30	5	2	—	—	—
Gray forest soils, "Pakhomovo" sovkhoz											
<2,5	23	13	9	—	—	10	34	28	23	14	8
2,5— 5,0	37	43	48	59	65	10—15	50	48	50	59	66
5—10	27	29	38	41	35	15—20	9	15	16	18	22
10—15	6	8	9	—	—	20—30	5	6	10	9	—
>15	13	7	2	—	—	30	2	2	1	—	—
Meadow-chernozem soils, kolkhoz imeni Vladimira Il'icha											
<3	32	35	24	22	11	10	43				
3—5	42	39	49	59	66	10—15	31				
5—7	15	14	17	11	16	15—20	23				
7—9	11	12	10	8	7	20—30	2				
>9	—	—	—	—	—	30	1				

Note: Comma represents decimal point.

having a great potential fertility, and high buffer-capacity and less fertilized, we see a clearly expressed variegation in the content of available phosphates and potassium. On a farmstead strip, in a former hemp field, the content of P_2O_5, according to Chirikov, is 10-15 mg, while the content of exchangeable potassium is 30-50 mg per 100 g of soil. On a 100 ha field adjoining the village and employing field rotation and used most often for row crops (potato, corn, and root crops) and consequently, systematically fertilized, the content of available phosphates and potassium on an average is twice as much as in soils of fields removed from the village.

Looking at Table 3 and Figures 1 and 2, we see that the decisive factor responsible for the variegation observed in the content of available nutrients in a plowed layer of cultivated soils is not so much the difference in the soils (groups and types) as the nature of the productive activities of the human being—the system of agriculture predominant on farms and, especially, the system of fertilization.

Soil Sampling Frequency in Detailed Chemical Mapping

What should the minimum soil sampling frequency be in order to describe sufficiently accurately the area under study? To what extent does this frequency depend upon relief, type of soil, degree of soil cultivation, and intensiveness of cropping?

Various instructions on this problem are given in handbooks on soil and soil chemical mapping. According to instructions for study of soils in the Ukrainian SSR (2), it is considered possible to compile chemical maps by taking one soil sample (one analysis) every 50 hectares. In the handbook prepared by the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR (4), it is recommended for chemical map compilation to take one soil sample every 10 hectares. In the Handbook of the All-Union Fertilizers and Soil Study Institute (VIUA) dealing with preparation and utilization of soil maps at kolkhozes and sovkhozes of the RSFSR (3), it is pointed out that an area which is characterized by one mixed sample, should not be larger than 10 hectares. In the German Democratic Republic and in several other People's Democracies (1), a mixed soil sample is taken from each hectare of plowland in compiling soil chemical maps.

The foregoing recommendations have no experimental basis. The indicated number of samples replicates the number of profiles (holes, pits, and surface samples) being laid out during

Table 5

Content of available phosphates and exchangeable potassium in mixed and individual soil samples

Soil	P_2O_5 (after Kirsanov)				K_2O (after Maslova)			
	Mixed		Individual		Mixed		Individual	
	M	*K*	*M*	*K*	*M*	*K*	*M*	*K*
Sod-podzolic soils, Mikheykovskiy sovkhoz								
Sod-weakly podzolic	10,4	72	13,2	80	10,1	28	9,4	39
Sod-moderately podzolic	6,8	67	6,9	71	11,4	28	9,8	40
Sod-weakly and moderately-podzolic (complex)	9,1	54	9,0	39	13,3	25	10,8	35
Sod-moderately and weakly-podzolic (complex)	13,1	69	14,9	91	13,9	43	12,5	59
Sod-moderately-podzolic (mixed forest)	5,8	40	4,6	67	9,8	18	7,2	41
Gray forest soils, "Pakhomovo" sovkhoz								
Light gray podzolized	4,6	52	4,6	63	10,3	21	10,1	23
Gray podzolized	6,3	45	6,8	58	23,7	65	23,2	60
Light gray gley	4,7	66	4,6	66	12,3	31	12,4	31
Gray-meadow	4,1	43	4,0	40	12,3	23	12,2	24
Light-gray strongly- and moderately-podzolic (complex)	3,3	37	3,0	49	13,3	25	12,7	28
Light gray strongly and moderately podzolic beneath forest (mixed forest)	4,1	55	4,2	23	21,6	3	22,2	16
Chernozem soils, kolkhoz imeni Vladimira Il'icha								
Podzolized chernozems	4,2	30	4,1	27	16,9	11	15,6	24
Leached chernozems	3,1	39			15,9	6		
Meadow chernozems	4,7	17	3,8	3	16,5	40	13,9	15
Chernozem-meadow	3,2	43	4,4	38	10,9	61	11,2	19
Podzolized chernozems beneath forest (deciduous)	3,3	24	3,0	15	13,0	13	13,3	8

Note: Comma represents decimal point.

soil investigations in accordance with map scale, and also replicates the number of local features based on soil surveying difficulty. The density (frequency) of soil sampling should differ for the various natural and farm conditions—one sampling frequency, for example, one sample every 10 hectares cannot be recommended for all zones and conditions. The number of samples required to compile chemical maps should be increased as soil becomes more complex, fertilizer application more intensive and varied, size of farm fields smaller, and field history records less detailed.

The results given in Table 4 have been computed as follows. A network of squares 2 x 2, 3 x 4, 4 x 4, and 5 x 5 ha was plotted on a map which was mapped by hectare (see the foregoing). Based on analyses of individual samples taken from hectare plots, mean values of phosphorous and potassium content were computed for the corresponding squares. Then the squares (of the different areas) were divided into groups according to their content of available forms of phosphorus and potassium.

From Table 4 and by comparing the maps compiled (which are not given in this article) with the maps shown previously, we see that: 1) Soil sampling frequency should be increased as we proceed from chernozem to sod-podzolic soils; and 2) within the limits of an individual farm (in all zones) soil sampling frequency may vary depending upon the previous history of land use.

On soils of the Mikheykovskiy sovkhoz, which is characterized by a great soil complexity and shallow soil profiles, and by the absence of a proper system of fertilizer application, soil chemical mapping should be carried out over a considerable part of the area by taking soil samples every hectare. However, for a large area of the sovkhoz, as we have established (on slightly fertilized and impoverished fields), we can limit ourselves entirely to taking a soil sample every 3-5 hectares.

On the gray forest soils of the "Pakhomovo" sovkhoz, the map compiled with an index frequency of 4-5 hectares, practically repeats the map compiled on a per hectare basis. But on farm crop rotation fields where fertilizers are applied in considerable amounts (but, as a rule, without any system), it would be advisable to map on a per hectare basis. At the same time on certain far-off scarcely fertilized fields we can limit ourselves in soil chemical mapping to taking one soil sample every 8-10 hectares.

On fields of the kolkhoz imeni Vladimira Il'icha, despite a comparatively smooth relief and similar soil, we cannot confine ourselves to recommending any one soil sampling frequency for the entire farm. Over a large area of the kolkhoz one sample every 8-10 hectares is sufficient, but near populated points we should practically double the number of soil samplings, i.e., take one sample every 4-5 hectares. With lesser frequency no substantial variegation in the content of elements studied in the soil will be noted.

We did not conduct systematic studies in the more southern steppe regions, which are characterized by an even smoother relief and a lesser fertilizer application, but there is no doubt that soil sampling frequency there may be even more reduced. But even on these soils on farms with intensive fertilizer application, for example, for sugar beets, high soil sampling frequency will be economically justified.

Comparing Analyses of Mixed and Individual Soil Samples

As was mentioned previously, individual soil samples were taken from each hectare together with mixed soil samples (from 10 pairs of samples) on all fields studied.

It is pointed out in all the handbooks on compilation of soil chemical cartograms that mixed samples must be taken for chemical analyses. It is assumed that this method will achieve a grading of natural variegation in the nutrient contents studied, a variegation common in such a heterogeneous and dynamic system as soil, and, besides, that the substantial effect on the analytic results of "accidental" spots of an increased concentration of substances as the consequence of uneven fertilizer application and placement, will be eliminated.

Table 5 presents the results of analyses and of mathematical calculation of many hundreds of mixed and individual soil samples taken on farms under study.

By comparing the results of analysis we see that the arithmetic mean values of P_2O_5 and K_2O of mixed and individual soil samples were very similar in most cases. Only for weakly podzolic soil did we observe a substantial difference in phosphorus content. The coefficient of variation for individual samples was somewhat higher than for mixed samples.

The closeness of the arithmetic mean values which characterize mixed and individual samples is explained by the fact that the mean values given in Table 5 for individual samples are arithmetic means of a very large number (several tens) of analyses. Consequently, these and other mean values approach roughly in equal measure the actual mean value M, characteristic of a given field or soil profile.

Based on the principle of large numbers we ought to admit that M values of mixed samples approach closer the actual mean value M. In such a case it would be interesting to compute and compare the individual deviations in the analyses of mixed and individual samples taken per hectare.

Figure 3 A and B represent graphically the content of P_2O_5 and K_2O in 25 individual soil samples, expressed in percent of phosphorous and potassium content in corresponding mixed samples (assumed, in each case as 100 percent). From the diagrams we see that:

1) the value by which the results of analyzing individual samples differs from analyses of mixed samples increases from south to north, i.e., from chernozem soils to sod-podzolic soils; and 2) the amplitude (range) of fluctuation in the analyses of individual samples relative to mixed samples increases with the degree of "cultivation."

Conclusions

1. To utilize efficiently soil fertility and properly use fertilizers in agriculture we must compile detailed soil chemical maps. Maps must be compiled, in the first place, on farms with intensive fertilizer application—on sovkhozes and kolkhozes engaged in cultivating commerical (technical) crops, vegetables and potatoes.

2. Soil sampling frequency in compiling soil chemical maps should be increased as soil becomes more complex, size of fields smaller, composition of crops in the field more diversified, and fertilizer application more intensive. In accordance with the nature of the soil a satisfactory soil sampling frequency when the scale of soil maps is 1:10,000 would be as follows:

a) within the sod-podzolic soil zone characterized by dissected topography, great soil complexity, and considerable variegation in the agricultural land use—one sample every 1-3 hectares.

b) within the gray forest soil zone, characterized by a moderately dissected topography and comparatively similar soil—one sample every 3-5 hectares.

c) within the forest steppe zone with meadow chernozem soils, podzolized and leached chernozems, with a slightly dissected relief and similar soils—one sample every 5-10 hectares.

3. Within each zone, even within the confines of one farm, soil sampling frequency cannot be the same. In the case of extensive fertilizer application even on plowed up, impoverished fields, the number of soil samples may be reduced, but on farms (or crop rotations) with intensive fertilizer application the number of soil samples, on the other hand, should be increased.

Detailed soil chemical mapping, as a rule, should be carried out based on previous large-scale soil mapping. However, because the

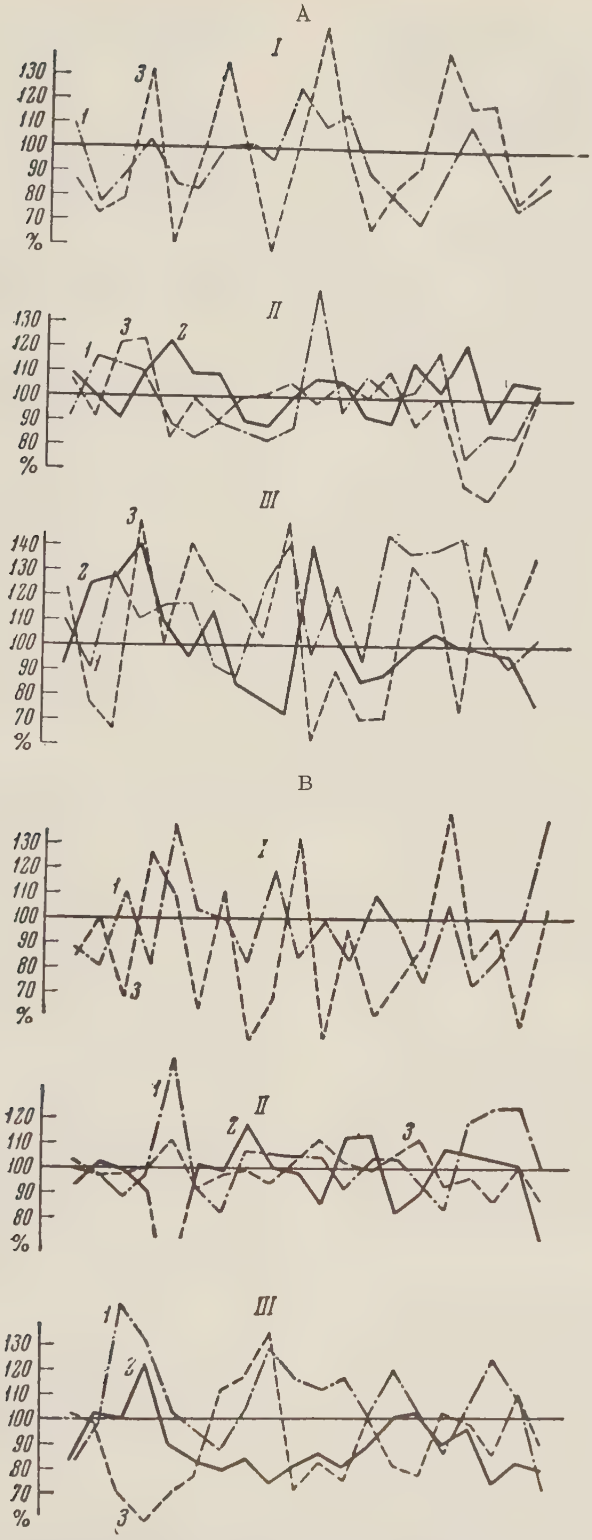


Fig. 3. - Content of available phosphates (A) and exchangeable potassium (B) in individual soil samples, expressed in percent of content of these elements in mixed samples. Sovkhozes: I - Mikheykovskiy; II - "Pakhomovo"; III - imeni Vladimira Il'icha. Soils: 1 - weakly-cultivated; 2 - moderately cultivated; 3 - well-cultivated.

content of available forms of nutrient elements in a plowed soil layer expresses not only and not so much the genesis of soil, but, to a great extent, the productive activities of the man, the land organization plan, and the farm field, the principal production unit of crop rotation should be adopted as the cartographic basis for detailed soil chemical mapping of soils of kolkhozes and sovkhozes.

Received March 21, 1960

BIBLIOGRAPHY

1. BARANOV, P. A., and N. P. KARPINSKIY. 1957. Fertilizer application in the German Democratic Republic. Sel'khozgiz.
2. Instructions and systematic data for studying soils of the kolkhozes and sovkhozes of Ukrainian SSR, 1957. Ukrainskiy nauchno-issledovatel'skiy institut pochvovedov. Khar'kov.
3. Methods of compiling and utilizing soil maps on kolkhozes and sovkhozes of the RSFSR. 1959. Vses. nauchno-issledovatel'skiy institut udobreniy i agropochvov. Sel'khozgiz.
4. Soil survey. 1959. Pochvennyy institut Akad. Nauk SSSR, Izd. Akad. Nauk SSSR.
5. Collection of systematic data for compiling soil agrochemical maps. 1933. VIUAA, Moscow, Sel'khozgiz.

MOST IMPORTANT RESULTS OF TEN YEARS' STUDY BY THE DZHANYBEK STATION, ACADEMY OF SCIENCES, USSR

A. A. RODE

The Dzhanybek Station (first results of activities already described)[1] was organized in 1950 as part of the Comprehensive Expedition on Problems of Field Shelterbelt Forestation, Academy of Sciences, USSR.

The Station was established on a tract at the southern half of the State forest shelterbelt (GZLP) from Chapayevsk to Vladimirovka, intersecting the northwestern part of the Prikaspiyskaya lowland. The Station is situated 5 kilometers southwest of the Dzhanybek Station of the Privolzhskaya railway and the rayon center of the same name of the Zapadno-Kazakhstanskaya Oblast'.

At the end of 1953 the station was transferred to the Institute of Forestry, Academy of Sciences, USSR, and in 1959 to the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR.

The initial objective of the station was to work out methods for cultivating shelterbelt plantations under the natural conditions of the semi-desert of the northwestern Pre-Caspian, as it applies to the Chapayevsk-Vladimirovka State forest shelterbelt. In 1953 at a time when the station had already made definite progress toward fulfilling the original objective, the direction and theme of its activities were expanded. A new policy was laid down, i.e., to devise methods for agiculturally reclaiming the semidesert of the northwestern Pre-Caspian. The initial objective was included as a whole in this new undertaking since the creation of tree-shrub plantations, which accumulate snow and thereby guarantee additional moisture, was one of the basic factors in the system of measures aimed at reclaiming a semidesert. The station is presently continuing its activities with this new objective in mind.

Station research is being carried out by scientific co-workers from 4 institutes of the Academy of Sciences, USSR—the Forest Institute (now the Forest Science Laboratory); the Soil, Botanical, and Geographical Institutes. The Forest and Soil Institutes play the leading role.

About 30 scientific workers have participated in the Station's activities during the 10 years of its existence: geomorphologist D. L. Mozeson; hydrogeologist M. P. Raspopov; soil scientists M. M. Abramova, A. F. Bol'shakov, T. Ya. Kissis, G. P. Maksimyuk, V. B. Matskevich, N. S. Oreshkina, M. N. Pol'skiy, and A. A. Rode; botanists I. V. Larin, T. K. Gordeyeva, I. V. Kamenetskaya, I. N. Olovyanikova, and I. V. Syrokomskaya; zoologists N. Ya. Burnasheva, L. G. Dinesman, and K. S. Khodasheva; silviculturists S. N. Karandina, P. L. Lapin, and S. D. Erpert; physiologists Yu. L. Tsel'niker, and N. A. Khlebnikova; agronomist V. Ya. Metelev and others.

The Dzhanybek Agricultural Meteorological Station organized in 1950 is working in close cooperation with the Station.

In their research work the co-workers of the Station are continually striving to be comprehensive, being guided at the same time by the principle of unity of nature which underlies the materialistic view on nature, and by the biogeosynoptic doctrine of academician V. N. Sukachev, where this principle has found concrete expression.

During the first year of operation the Station was engaged in studying natural conditions, profiting by both literary data and its own new investigations. The results of studies by the Station belonging to the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR, which worked in the vicinity of Dzhanybek in the 1930's headed by V. A. Kovda with the assistance of A. F. Bol'shakov, greatly aided in enabling us to become familiar with natural conditions.

The results of studying the natural conditions of the station are as follows. The climate of the station is described by the following indices (Fig. 1). Mean annual temperature equals 6.9°C with fluctuations from 5.6°C to 9.1°C. Annual total precipitation equals 280 mm, 125 mm of which occurs during the cold months (October-March), and 155 mm during the warm period of the year (April-September). Relative humidity of air from May to September is 49%-57%. Average number of dry days (with a relative humidity of air below 30% even though for one observation period) is 64. Potential evaporation (computed by Davydov's formula) for April-October equals 830 mm. The yearly value of the moisture

---

[1] A. A. Rode, "Studies of the Dzhanybek Station of the Comprehensive Expedition on Problems of Field Shelterbelt Forestation." Pochvovedeniye, No. 2, 1952.

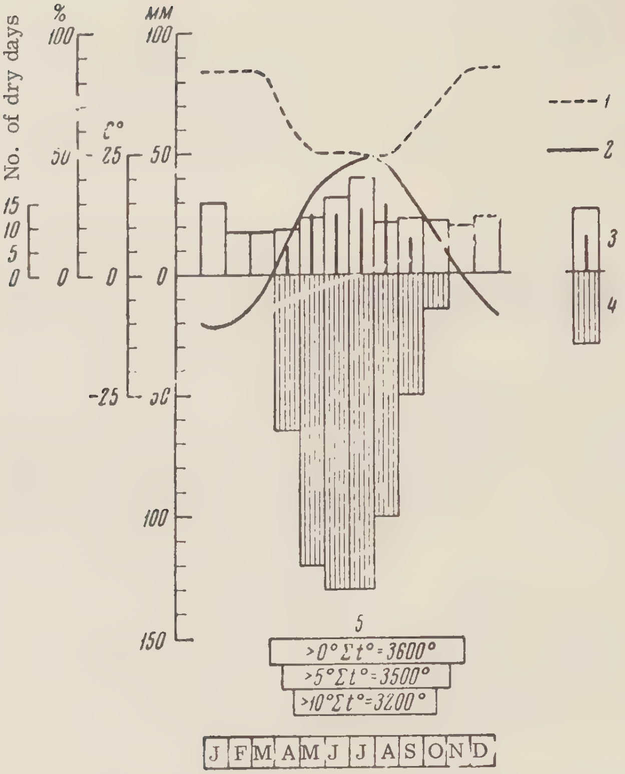


Fig. 1. - Annual rate of certain meteorological indices from data of the El'ton Meteorological Station.

1 - Relative humidity of air; 2 - air temperature; 3 - precipitation and number of dry days; 4 - potential evaporation; 5 - periods with temperatures above 0°C, 5°C and 10°C.

coefficient is 0.31, dropping in August to 0.12. Number of days with hot and dry winds during warm months is 80.

An analysis of meteorological data has shown that a perennial cycle of operations (which is illustrated by Fig. 2 for annual total precipitation and annual value of potential evaporation) is characteristic of the climate of this region.

The surface of the northwestern part of the Prikaspiyskaya lowland is made up of many meter layers of fine loess-like carbonate clay loam, very similar both in extent (space) and in its own layer. The water table is at a depth of 6-7 m in this layer.

In character of relief the northwestern part of the Pre-Caspian is, generally, an ideal plain. Large valleys and lagoons, on the one hand, and a plain between valleys, on the other hand, are the basic surface elements which may be conditionally assigned to the elements of meso-relief. The large valleys and lagoons are closed flat-bottomed depressions with a relative depth of 1-2 m for the valleys, and 2-3 m for the lagoons. The valley area ranges from 1-2 to 100 hectares and the lagoon area to several thousand hectares. A clearly expressed microrelief is characteristic of the plain between valleys. Elements of microrelief are first, hollows or cirques—closed flat-bottomed depressions 30-40 cm deep and with an area ranging from several tens to thousands of square meters; second, microelevations, which, by merging together, form a solid background; small flat hillocks—marmot knolls can be seen on them; and thirdly, microslopes linking the depressions to microelevations.

The extent of erosional forms of relief is confined by narrow strips along a few river valleys (the Khara, Ashche-Uzek, Samoroda Rivers) and near the basins of Lake El'ton and the Khaki muds, where we encounter shallow short ravines.

The foregoing forms of meso- and micro-relief play an unusual role in surface water redistribution and, by it, affect also both the soil formation and the vegetation distribution on the various elements of meso- and micro-relief. Moisture redistribution begins in winter when far greater quantities of snow are accumulated in depressions than on micro-elevations. It is intensified in the spring when the melted snows rush into the depressions. According to station observations the spring increase of moisture storage in the soil is, on an average, for a 7-year period, 100 mm on microelevations, 140 mm on microslopes, and 320 mm in depressions.

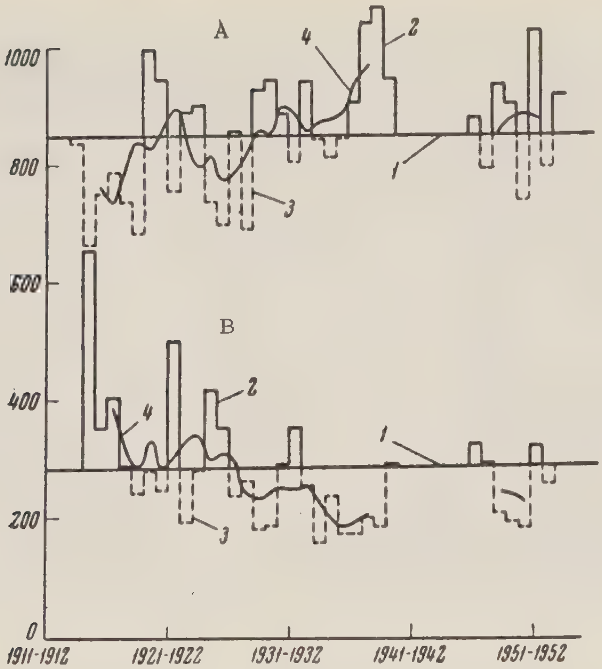


Fig. 2. - Perennial variability of annual total precipitation and potential evaporation values during warm half-year.

A - potential evaporation during warm months; B - precipitation, annual total. 1 - mean values; 2 - sums exceeding perennial mean; 3 - sums, below perennial mean; 4 - curve constructed from running 5-year mean.

During certain spring periods we observe a flow of part of the melted snow onto lagoon and large valleys. This runoff is due to the large amount of precipitation during the previous autumn which causes soil wetting and the loss by soil of water permeability during freezing.

Owing to such surface water redistribution in the depressions of meso- and micro-relief, a water regime of the periodic runoff type is created. As a result, the soil contains no easily soluble salts. In the large valleys and depressions an abundant vegetation with a variety of grasses is developed. The basic components of this vegetation are wheat grass, steppe grass, Lessing feather grass, and lucerne. In the depressions are found also wild-growing shrubs—2 species of spirea, leafy and crenate St. John's wort. Under such vegetation are formed dark-colored soils, which remind us somewhat of leached chernozems having a well-developed humus horizon, containing up to 5%-6% humus with a thickness to 40 cm. Figure 3, A shows the salt profile of such a soil (a) and moisture distribution in the soil during spring and fall (b). These soils have a high natural fertility. Thickness of soil profile which is determined by the thickness of the layer inhabited by roots is 3 m or somewhat more. The mean value of annual moisture balance, including summer precipitation, in the depressions is 440 mm, 55 mm of which pass into ground waters while 385 mm is lost to evapotranspiration. There are no salts in these soils, except calcium carbonate.

On the microslopes the water regime is classed as non-leaching type. The greatest depth of wetting does not exceed 120-130 cm, while average depth of wetting is 60-70 cm. The principal components of vegetation are wheat grass, steppe grass, and pyrethrum. Beneath them is formed a soil of the light chestnut solonetz-like group. The salt profile of this soil and the moisture profiles during spring and fall are shown in Figure 3, B. Of the plants mentioned previously, the roots of wheat grass and steppe grass penetrate to a depth of 60 cm, while the roots of pyrethrum penetrate to a depth of 120-130 cm. The thickness of the soil profile is also determined by these latter values. On the lower boundary of the profile which desiccates activity of the pyrethrum roots, a low moisture—equal wilting moisture — is constantly maintained. Deeper, in the soil layer, the moisture gradually increases, and in the 4-meter soil layer the upper boundary of the capillary fringe of ground waters appears. Owing to such moisture distribution in the soil layer, a suction force gradient is created which is responsible for the very slow (owing to low moisture conductivity of the dry layer) but continuous upward flow of moisture from the ground waters. These ground waters have been somewhat salinized (to 6-7 g of salt per liter, primarily, sodium sulfate).

Being drawn to the lower boundary of the soil layer, the upward flow moisture is drawn off by plants, whereas the salts are accumulated at this boundary. The annual moisture balance,

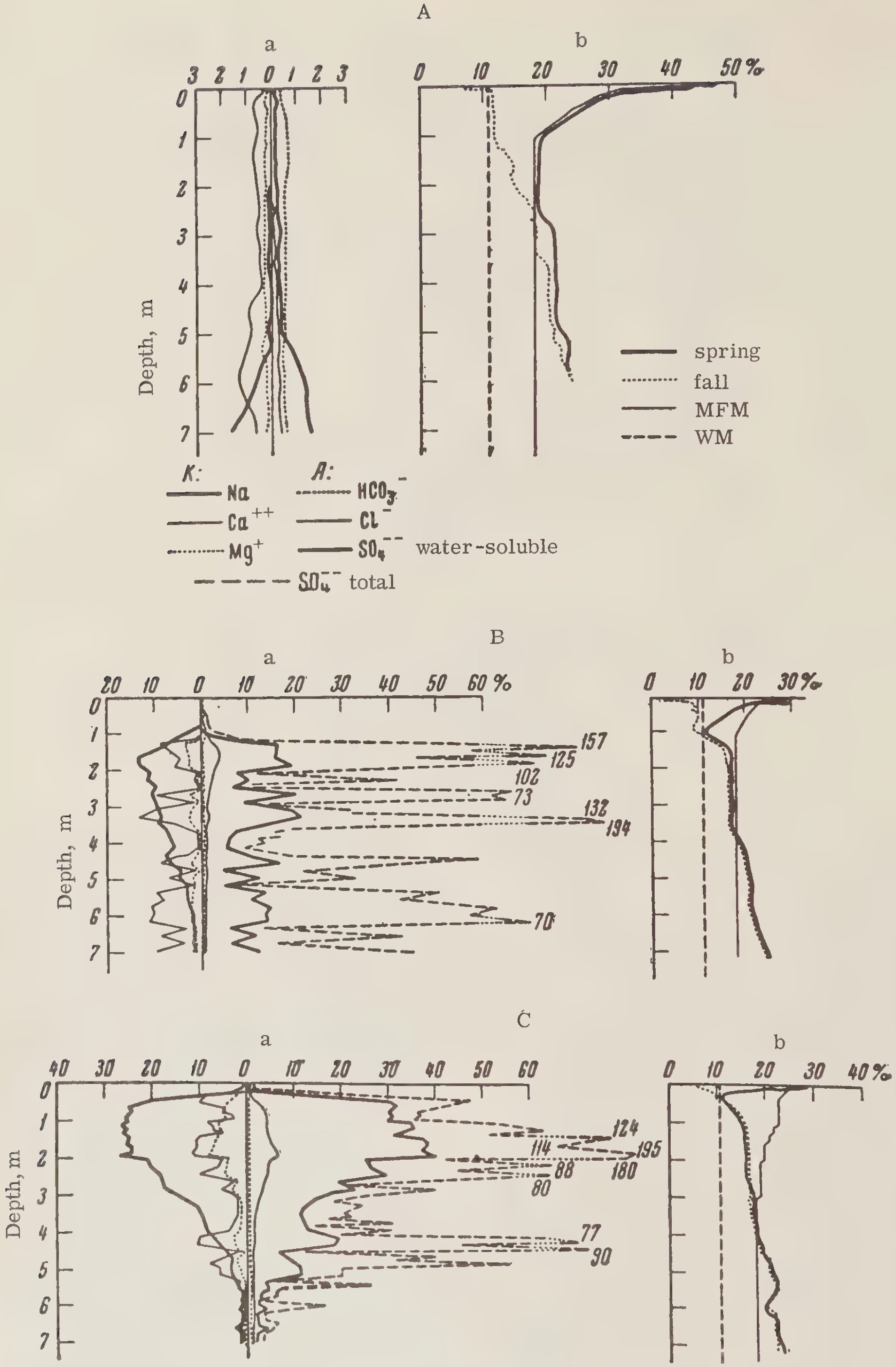


Fig. 3. - Soils of the plain between valleys.

A - Dark colored soil; B - light chestnut soil; C - solonchak-like solonetz; a - salt profile; b - spring and fall moisture profiles.

including summer precipitation, is, on an average, for a 7-year period, equal to 260 mm, 10 mm of which pass into ground waters with the remainder lost to evapotranspiration.

There is no continuous wetting on microelevations either. The greatest depth of wetting is 40-50 cm with the average depth of wetting 25-30 cm. Vegetation here consists of two components

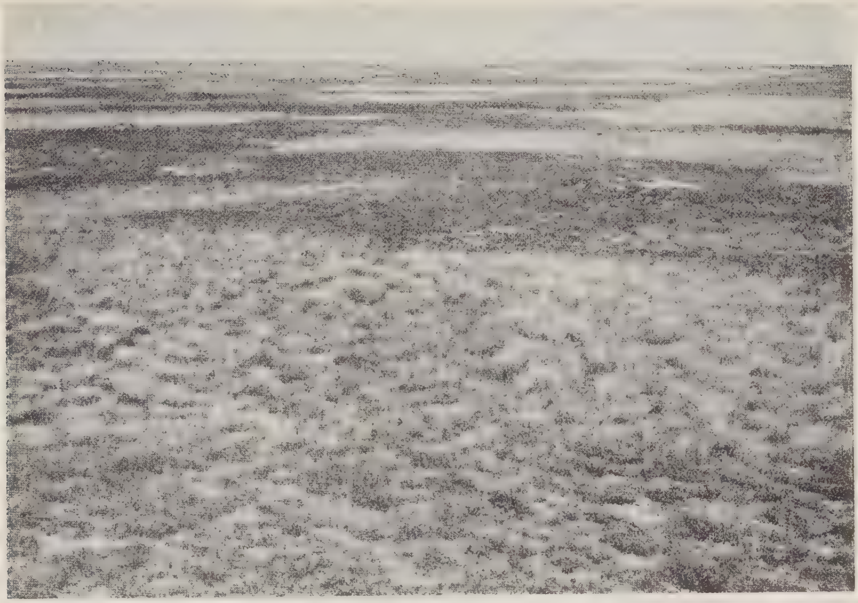


Fig. 4. - Complex vegetation on the plain between valleys (depressions): Dark spots are black wormwood on solonchak-like solonetzes; light spots are varieties of grasses on dark-colored soils of depressions.

—black wormwood and Kochia. Beneath them are formed solonchak-like solonetzes, the salt and moisture profiles of which are depicted in Figure 3, B. The solonetz profile is made up of a top solonetz horizon several centimeters thick, a solonetz horizon 20-30 cm thick, a first sub solonetz salinized horizon, permanently dry, with an original sand-shaped structure (despite a fine clay loam texture), a second sub solonetz salinized horizon, minus such structure with increased downward moisture, and a gypsum salinized horizon. The salt content in the two sub solonetz horizons are more or less the same and is 2.5%-3.0% of the soil weight, with a predominance of sodium sulfate in salt. Deeper, the salt content gradually decreases and in the 6-meter layer the salt content is as great as in the ground water saturating it. The salt content in ground water is 10-20 g per liter. The roots of black wormwood terminate at a depth no more than 50 cm, that is, immediately beneath the solonetz horizon. The roots of kochia extend to a depth of 2 or even 3 meters. The roots of saltwort sporadically found on solonetzes, extend even further, to 4.5 meters. Thus, the thickness of soil layer is roughly 3 meters or somewhat more. Moisture is removed from this entire layer by the suction processes of kochia and halophytes. As a result, a moisture gradient and, consequently, a suction force gradient, which here is the reason for the slow upward flow of moisture, are formed in the lower part of the soil layer. In contrast with light chestnut soil, suctioning of upward moisture takes place not only at the lower boundary of the soil profile but throughout the entire profile, as a result of which salts are accumulated in the entire profile. The water regime of solonchak-like solonetz is a combination of non-leaching with percolation. The annual moisture balance of solonetz equals, on an average, including summer precipitation, 220 mm; 10 mm of this pass into ground waters as vapor while 210 mm is lost to evapotranspiration.

These are the soil characteristics of the plain between depressions (valleys) where the complexity includes ground waters, soils, and vegetation (Fig. 4). The contours of the individual components of soil and vegetation, as seen from the soil plan (Fig. 5), are small: their diameter is not more than 20-30 meters and frequently less. Approximately half of the 3 principal components of the complex applies to solonchak-like solonetzes, a quarter to light chestnut soils, and a quarter to dark-colored soils of depressions. A stable ground-water complexity during which salinized waters over a distance of several meters are replaced by almost fresh water is evidence of the absence of any noticeable general movement of ground waters, in other words, evidence of ground-water stagnation.

Dark-colored soils are also being developed in large valleys (depressions) but beneath the humus horizon in these soils there is a clay forming horizon, enriched by clay particles. Solods are formed in the lagoons.

As mentioned previously, the ground waters beneath all elements of meso- and micro-relief are, roughly, at one and the same depth—about 6-7 meters. Only during the spring beneath depressions and during the flooding of valleys below them does the ground-water level, as a result of percolation from melted snow, rise forming cupolas beneath these depressions. These cupolas quickly disappear through spilling, and, partly, from the moisture being withdrawn by plants, which takes place beneath the depressions

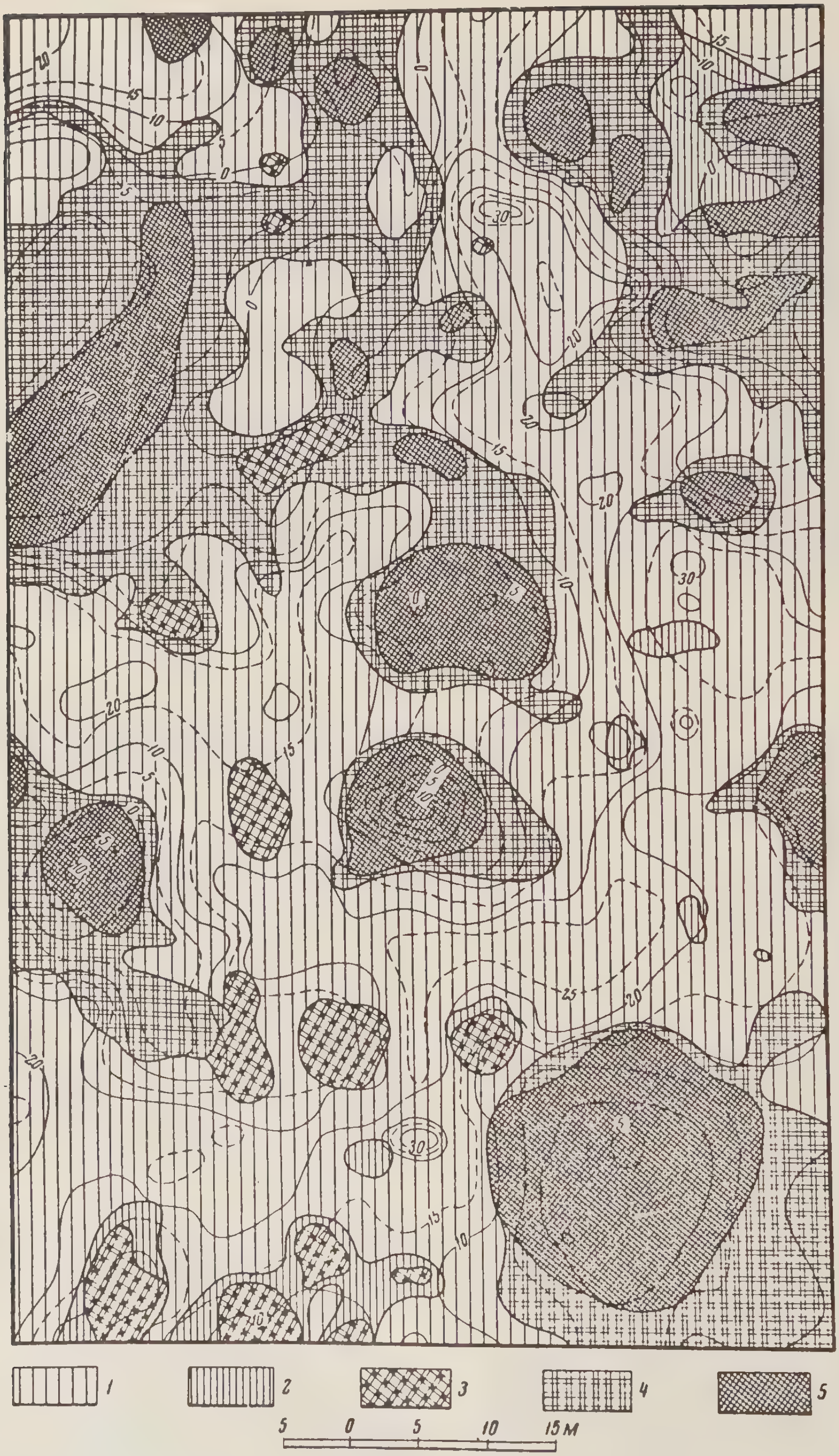


Fig. 5. - Soil plan of one of the key areas.

1 - Solonchak-like solonetzes; 2 - steppe solonetzes; 3 - dark chestnut soils of shallow depressions; 4 - light chestnut soils of microslopes; 5 - dark-colored soils.

and large hollows (valleys) and microelevations. There is no direct moisture withdrawn except beneath the microslopes. Thus, the balance of ground waters, as a whole, is determined by the moisture exchange between the ground waters and the atmosphere; moisture is removed solely through plants. This, obviously, explains also their depth (6-7 meters) which corresponds to the sum of the greatest depth of root penetration in the depressions and on microelevations (300-320 cm) and the thickness of the capillary fringe (also 300-320 cm). If in years or long standing periods of increased precipitation and increased infiltration into ground waters the ground-water level begins to rise, the moisture being drawn from the ground waters by plants will be intensified, which will automatically lead to an accelerated decrease in the level. As soon as the level drops to 6.5-7.0 meters, the upper boundary of the capillary fringe will break away from the lower boundary of the layer inhabited by roots, and the ground water removal by suction will be lowered and the drop in ground-water level slowed down.

The type of water regime for the foregoing soils, which make up the soil of the semidesert, is determined by two factors: on the one hand, by the position which soil occupies in the meso- or micro-relief, and, on the other hand, by the biological characteristics of plants growing on it, principally, the depth of plant-root penetration.

These, in short, are the natural conditions of the Dzhanybek Station.

The farming in the area has been predominantly livestock (chiefly sheep raising) for a long time. In addition, animal husbandry has been based until recently, almost entirely on the utilization of natural vegetation year-around pasturage with a very small amount of hay mowing. Thus, during winters characterized by a large snow cover, severe ice crusts, etc., when the natural vegetation becomes inaccessible, we frequently observe here a mass dying-off of cattle due to lack of feed. The rapid development of animal husbandry at present urgently demands total reconstruction of the feed base, which can be realized only by extensively introducing forage crop culture to silage and hay. However, we can also achieve much by the efficient utilization of natural vegetation. A study was made at the station over a 5-year period by a group of botanists headed by academician I. V. Larin, on the productiveness of this vegetation. It was shown that we can obtain 5-6 centners per hectares of feed (converted to dry mass) by rotating 2-3 times-a-year grazing with once-a-year grazing, provided we introduce a 5-year pasture rotation. In addition, about one hectare of pasture land is required for one sheep.

Farming has existed here for a long time, but, until recently, has been based chiefly on the utilization of large valleys, the total area of which is only about one-tenth of the entire territory. Grain crops (chiefly wheat) and melons have been planted in the large valleys; fruit gardens have been created. The absence of proper agricultural technology and fertilizer application has led to the fact that soils of the large valleys have lost to a large extent the high natural fertility characteristic of them. This is particularly caused by the fact that they are overgrown with annual and perennial weeds. But, irrespective of this, the total area of large valleys cannot satisfy the rapidly growing demands of agriculture. Therefore, in recent years the soils of solonetz complex have begun to be plowed in elementary fashion, employing the usual farming practices with the complete absence of any land-improvement measures. By utilizing soils thusly, a satisfactory harvest can be obtained only during years of great moisture, that is, an adequate harvest, at best, twice in 10 years. During the remaining years the harvest is negligible.

An analysis of the foregoing natural conditions shows that we must carry out two principal practices for a successful agricultural reclamation of the soils of solonetz complex: first, melioration (desolonetzization and desalinization) of solonchak-like solonetzes which cover half of the entire plain area between valleys (depressions) and, secondly, additional moisture necessary on the one hand, to carry out successfully the meliorative process and, on the other hand, to increase moisture supply to plants.

The station has been working and is continuing to work towards realization of these two practices. In line with this the plain between the valleys (depressions) with its complex soil and vegetation has been, and continues to be, the most important objective of the research and experimental activities of the station. The large valleys (depressions) are the second most important objective.

A study of the natural conditions has enabled us to observe by the end of the first year of station activities the basic methods for carrying out the foregoing practices. For reclaiming solonchak-like solonetzes, the method proposed in the 1930's by V. A. Kovda and A. F. Bol'shakov was chosen, which consisted of utilizing gypsum found in the solonetzes at a depth of 35-50 cm for desolonetzizing the solonetzes. Calculations based on chemical analysis show that this gypsum content is 15-20 metric tons per hectare and these gypsum amounts are fully adequate for replacing the total exchangeable sodium. We can utilize gypsum by deep plowing to a depth of 50 cm, which brings the gypsum into the plow layer. Plowing to a depth of 20-22 cm should precede deep plowing in order to assure the best mixing of the soil mass in the plow layer, and, after deep plowing, we should cultivate the soil with heavy disc harrows (so as to mix the soil and level the plowland surface).

There are no surface or underground waters in this region which can be used for irrigation. Therefore, additional moisture can be obtained only through snow accumulation, which is promoted by severe winter winds, causing the snow to be shifted in large quantities. Planting tree-shrub windbreak rows of narrow few-row strips laid out more or less perpendicularly to the prevailing direction of winter winds has been recognized as the best principal means of accumulating snow. In this case planting rows in a meridional direction would be most beneficial. As an auxiliary means of snow accumulation, which would be advisable during the first few years, when the tree shrub rows are still small,

Fig. 6. - Ten year-old 3 row strips of 1951 planting on soils of a solonetz complex.

Table 1

Mean water content in snow before snow melting, mm depth of water

Year	Open steppe	Strips of 1951 planting		
		3-row	5-row	7-row
1952	88	145	128	128
1953	122	160	176	232
1954	44	96	86	109
1955	No stable snow cover			
1956	170	490	450	445
1957	40	70	78	73
Mean	93	192	184	197

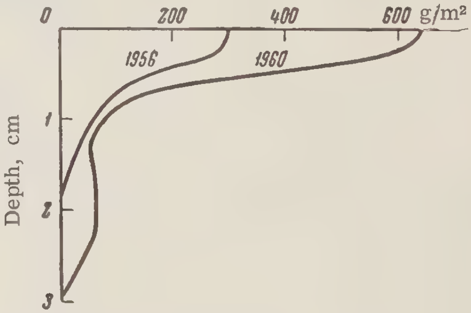


Fig. 7. - Masses of fine (finer than 1 mm in diameter) roots, in g/m^2 (in a 10-cm layer), of a small-leaf elm on reclaimed solonchak-like solonetzes in the sixth and tenth year.

we could use cover-strips of tall annual crop plants (sorghum, sunflower, etc.).

The station began experimental research in 1951. For this research a 2-kilometer segment of the Chapayevsk-Vladimirovsk State Forest Shelterbelt (GZLP) was selected consisting of 4 strips about 60 meters wide with 300 meter spacing between strips. Besides this segment of GZLP, the station was assigned a 190 ha strip from the state land reserve of the Dzhanybekskiy Rayon.

In 1951, 3, 5, and 7-row strips were laid out over an area of about 7 hectares. The excellent growth of these rows in the first year, which was characterized by not too favorable weather conditions, provided a basis for enlarging the experimental area to 30 hectares in the following year. This area has continued to expand each year.

After 1953, in connection with the above-mentioned change in the principal objective of the station, the station could be no longer satisfied with only a strip of the State Forest Shelterbelt (GZLP) because this strip did not meet the requirements of agricultural production. Therefore, in 1955, the station set up another experiment on the soil of a nearby kolkhoz "Pobeda," in the Pallasovskiy Rayon, Stalingradskaya Oblast', over a 114 ha area under kolkhoz agricultural production conditions. Twenty three-row kilometer segments (sections) were planted on this strip in 1955 and 1956. At present, the total area of soils of solonetz complex covered by experiments is 172 hectares. Forty-four hectares (converted for dense planting) contain various tree shrub plantings.

All experimental activities at the station were accompanied by various observations and

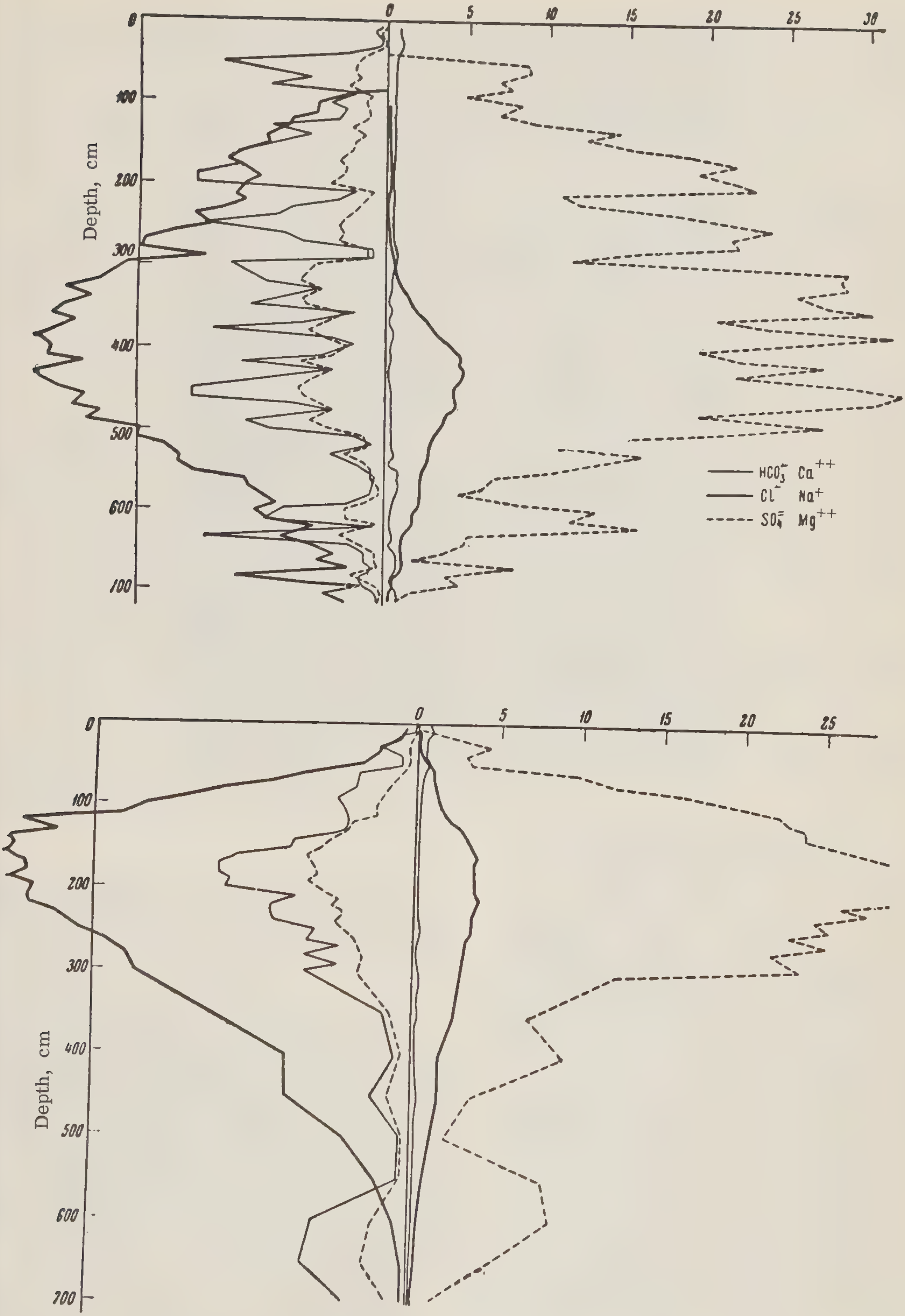


Fig. 8. - Salt profiles of reclaimed solonchak-like solonetzes 8 years after meliorative plowing and row planting.

A - under 3-row strip; B - under area between strips, covered by annual crops, 1959. Left, the cations; right, the anions.

analyses. Most important of these were observations on the snow cover, water, salt and gas regime of soils, growth and development of tree plantations and agricultural crops, study of root systems of tree and shrub plants and annual cultivated crops, observations on the transpiration of these plants, their water regime, photosynthesis, etc.

The foregoing experiments have enabled the station to establish and demonstrate the vital nature and productive expediency of the semidesert reclamation system being developed by the station. An analysis of several species has shown that small-leaf elm from the tree species, golden currants, Tatar honey suckle, and narrow-leaf Russian olive from the shrub species, are the most suitable for initial cultivation on soils of solonetz complex. Golden currants, moreover, begin to bear fruit in the third or fourth year, yielding a large harvest of berries only slightly inferior in quality to black currant.

These species on the experimental strips of the station also constitute a large part of the plantings. Three-row strips, which in no way were inferior in snow accumulation to the 5- and 7-row strips were recognized as the most expedient of all the row types studied. Experiments are presently being conducted on 1 and 2-row strips.

In a production experiment where annual plants were begun to be sown in the third year, heights of 250 cm were reached in the fifth year. Figure 6 shows the present-day picture of rows planted in 1951. The roots of small-leaf elm on reclaimed solonetzes reached depths of almost 200 cm in the sixth year after planting the rows and 300 cm in the tenth year, as seen in Figure 7.

We can determine to what extent the rows have fulfilled their basic purpose by the water storage in the snow in the open steppe and among rows before the snow melted (Table 1).

The rows, on an average, double the water content; the soil acquires roughly an additional 100 mm of moisture in the area occupied by the rows and by the spaces between the rows. As a result, the water balance of reclaimed solonchak-like solonetzes reached on an average for 4 years, including summer precipitation, 290 mm that is, an increase of more than 100 mm. This increase in moisture rotation also guarantees, on the one hand, an excellent growth of the rows themselves and, on the other hand, the success of the meliorative process and, thirdly, the possibility of cultivating agricultural crops on areas between rows.

The rate of the meliorative process can be determined from the following data. Water permeability of solonchak-like solonetzes, which is one of the clearest indicators of the influence of solonetzization, has appreciably increased. The intake period for a standard quantity of 50 mm of water is reduced from 50 to 17 minutes, and of 100 mm from 1 hour and 40 minutes to 33 minutes, that is, in both cases, reduced to one third.

The salts in a profile of solonchak-like solonetzes noticeably move downwards, as seen by comparing Figure 8 with Figure 3, B. In addition, the greatest leaching of salts has occurred beneath the 3 row tree-shrub strips (Fig. 8, A) where the 2-meter layer of soil has been completely leached of the chloride ion. The maximum chloride ion content dropped to the fourth meter layer in the fourth year and to the fifth meter layer in the eighth year, with the total maximum salt content also removed to the fifth meter layer.

Salts were leached less deeply beneath the area between rows (Fig. 8, B) where annual crops were being cultivated. Here the maximum salt content dropped to the second meter layer; only the top meter layer was almost completely leached of the chloride ion while the maximum chloride ion content moved into the third meter layer. No noticeable downward movement of salt occurred beneath perennial grasses sown in the year following meliorative plowing.

Physiological studies have shown that the transpiration rate of tree and shrub plants depends, in the first place, upon the moisture supply in the top 2-meter layer of soil. The drying up of this layer causes a sharp reduction in the rate of transpiration even when (as happens on large valleys [depressions] with nonsalinized soils) the plants can utilize moisture from the capillary fringe of ground waters. Therefore, the transpiration rate curve undergoes a sharp drop in June and is then kept at a low level. However, the moisture supply from the capillary fringe guarantees stability of moisture content for leaves, and more active stoma activity during the period when there is no longer any available moisture in the top 2-3 meter layer of soil.

The presence of salts in the soil solution during low concentration causes an increase in the suction force of osmotic pressure of a cell fluid in root cells. With a higher concentration a toxic action of salts develops which causes a decrease in root activity.

The rate of transpiration and photosynthesis is directly related to the moisture of the top half meter layer of soil. A sudden change in both these values is observed when the moisture crosses 70% of the value of minimum moisture capacity.

The Station began experiments on planting agricultural crops on reclaimed soils of solonetz complex on its own strips in 1954 and on the production experiment strip at kolkhoz "Pobeda" in 1958. A number of crops were studied of which we shall mention the most interesting. Spring wheat yielded a harvest of 6.8 cntr/ha in 1954; 15.3 cntr/ha in 1956; 14.0 cntr/ha in 1958 and 15.0 cntr/ha in 1959. All were grain yields from an area of 2-3 hectares. Especially significant is the 1959 harvest (Fig. 9) when a total of 25 mm precipitation fell during the vegetative stage of wheat and the yield was 15.0 cntr/ha. Neighboring kolkhozes even on soils of large valleys, obtained during this period no more than 5-6 cntr/ha.

Experiments were conducted twice with perennial grass mixtures. The first time, the grasses were sown immediately after deep plowing with rows of sorghum, which were also sown in the second year, after which snow retention (ridging)

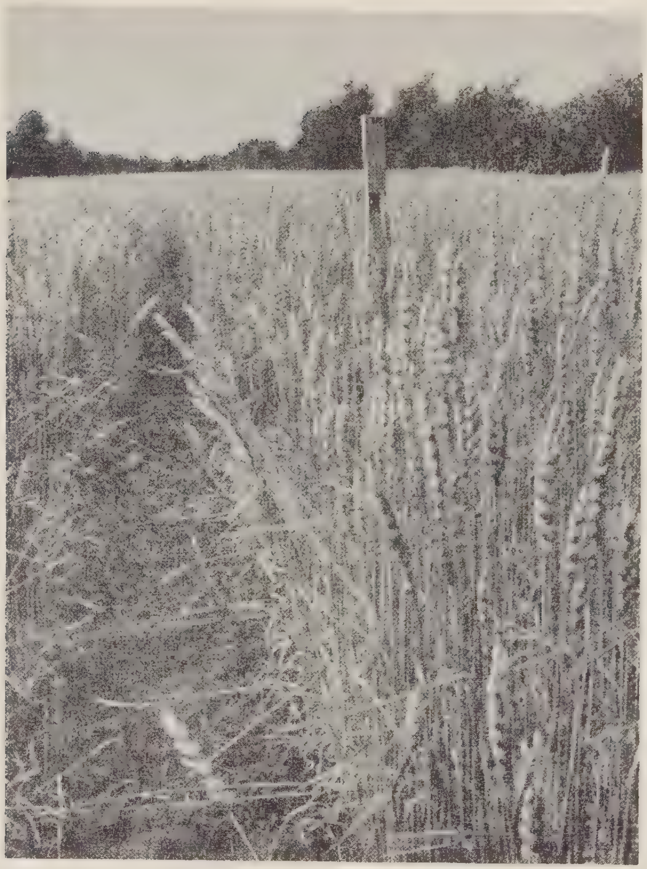


Fig. 9. - Spring wheat on reclaimed soils of solonetz complex in 1959 (eighth year after meliorative plowing) among rows planted in 1952. Yield is 15 centner per hectare.

was no longer carried out. Hay yields in 7 consecutive years were 6.7, 26.0, 15.0, 10.0, 17.4, 6.0, 12.0, an average of 13.3 cntr/ha. In the second experiment which was set up between tree-shrub strips in the fifth year following start of melioration, hay yields were, for 3 consecutive years, 9 cntr/ha (first year); 26 cntr/ha (second year); and 42 cntr/ha (third year) from an area of about one hectare. In small plot experiments the following hay yields were obtained: Sudan grass 41 cntr/ha; sorghum 28-38 cntr/ha; corn 22-38 cntr/ha. Sugar beets yielded 98-131 cntr/ha. From these values we see that on soils of a solonetz complex being reclaimed in the manner proposed by the station, we can obtain very satisfactory yields almost every year, except when there is no stable snow cover. This happens approximately once every 10 years (for the period of station operation 1955 was one).

Observations on the water regime of reclaimed soils showed that the foregoing wheat yields require 250-300 mm moisture (total consumption). Considering the fact that total precipitation during the wheat vegetative stage is about 75 mm and during the fall-winter-spring period 125 mm, we see that we must provide an average of about 100 mm additional precipitation. This amount, as we have seen previously, is being provided by snow accumulation by tree-shrub rows.

As mentioned previously, the large valleys (depressions) were the second objective of station research. Eighteen hectares of various experimental plantings were established on the large valleys: pure crops of 12 tree and shrub species (3 hectares); oak (4 hectares); fruit garden (2 hectares); dendrology park (6 hectares), etc.

The main purpose for planting oak was to study this valuable species in detail under given soil and climatic conditions. Experiments with different systems of planting acorns and seedlings of various geographic origin were accompanied by detailed silviculture, physiological, and other studies. It was discovered that oak on dark-colored soils of large valleys (depressions) is a species with great prospects for green plantations and for meeting local requirements for oakwood. Oak fruiting under these conditions began in the fifth year.

A climatic analysis of about 150 varied forms of tree and shrub species is being made in the dendrology park. The results permit us to recommend a number of valuable species (for landscape purposes) for green plantings on large valleys.

Much comprehensive research by silviculturists, physiologists, and soil scientists has been carried out on the pure stands of tree species for studying moisture requirements, growth, and development and water regime of plants, related to several species. The characteristics of these species in given relationships have been developed, affording us a sound basis to recommend them for various requirements. It has been established that the creation of tree plantings on dark-colored soils of large valleys radically changes the type of water regime of dark-colored soils: periodic leaching is replaced by suction-seepage. Recommendations have been made on the problem of the safe maximum valley (depression) area which can be planted with trees without fear of inducing an influx of salinized water from under the neighboring strips on the plain between valleys.

Observations, being conducted in the fruit garden, on the growth, development, and phenology of various varieties of apples (10 varieties); pears (6 varieties); cherries (7 varieties) and their fruiting provide objective data for selecting varieties suitable for local conditions. The garden began to bear fruit in the eighth year.

Experiments on planting annual and perennial forage crops from which very high yields were obtained were conducted on dark-colored soils of the large valleys by a group of coworkers of academician I. V. Larin (A. G. Babich, V. Ya. Metelev, Khuan Ven'-uy). Thus, Sudan grass yielded 63 cntr/ha of dry mass, alfalfa 43 cntr/ha in the second year, and 75 cntr/ha in the third. Awnless bromegrass yielded 36 cntr/ha in the second year after planting and 49 cntr/ha in the third year. Desert wheatgrass yielded 37 and 69 cntr/ha, respectively, in the second and third years; a grass mixture of alfalfa +wheat grass +bromegrass yielded 13 cntr/ha during the year of planting, 39 cntr/ha in the second year and 83 cntr/ha in the third. The different varieties of sorghum yielded between 49 and 102 cntr/ha. All these data show that planting forage crops on dark-colored soils of large valleys (depressions) can be an enormous help in resolving the feed problem.

Future objectives of the station in the field of scientific investigations include, first, a long-term study of the rate of the meliorative process beneath various vegetation with varied farming practices and combinations of weather conditions, and, second, a study of the growth and development of tree-shrub plantings and of annual crops and the productiveness of these crops in connection with the salt and water regime of soils. The results of these studies will make it possible to perfect the semi-desert reclamation system being devised by the station.

In addition, we will have to work out such problems as the width of the rows, the width most suitable for areas between rows, testing new species of tree and shrub plants on reclaimed soils of solonetz complex, and also, new species of agricultural crops.

Finally, the system of semi-desert reclamation being proposed by the station, should go beyond extensive testing under production experiment conditions and begin to be put into actual practice.

AGRICULTURAL CHEMICAL CHARACTERISTICS OF SOILS OF THE MOSCOW RIVER FLOOD PLAIN (BOTTOM LAND)

L. I. KORABLEVA, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

In connection with the organization in the Moskovskaya Oblast' of large-scale specialized sovkhozes, many of which are on flood-plain soils, the detailed study of flood-plain soils has taken on great practical significance.

The present study offers data on chemical investigations of Moscow River flood-plain soils. These investigations were begun in 1951 at the lower course (Faustovskoye extension fields of the kolkhoz imeni Stalina) and continued subsequently over the entire Moskvoretskaya flood-plain.

Soil samples for chemical studies were selected bearing in mind to obtain data both on soil characteristics of the genetic zones of the flood-plain (along the river, central, and terrace flood-plain) and on the characteristics of changes in soil properties lengthwise, along the course of the Moscow River, from the upper reaches to its mouth where the Oka River joins. On the most typical segments and expansions of flood-plain (most frequently cultivated for vegetable or forage vegetable crop rotations) profiles have been laid out (in a direction from the river bed to the first terrace above the flood-plain) and soil samples taken from the genetic horizons of the soil profile. For mass analyses (determination of available forms of nitrogen, phosphorus and potassium) mixed soil samples were taken, for the most part, from the plowed layers of flood-plain soils. Soil analyses were made by the senior laboratory worker G. A. Achkasova.

At the upper course (to the village Tuchkovo) the Moscow River runs in a comparatively narrow and shallow water channel. Noticeable flood-plain expansions (Aksin'inskoye, Rublevskoye, Tushinskoye expansions) set in only after the city of Zvenigorod. The largest massifs of flood-plains are found at the lower course of the Moscow River (below Moscow) where there is a fairly wide, well-developed river valley, and where the river forms several large lake-like expansions (the Bykovskoye, Ramenskoye, Faustovskoye and Kolomenskoye expansions) having a diameter of 5-8 kilometers.

The along-the-river-side, the highest part of the Moscow River flood-plain, is made up of stratified sandy-silty or coarse clay loam alluvium underlain with sand and sandy loam. Here sod, silty-sandy loam and coarse clay loam soils with a thin humus horizon, a blocky, granular, unstable structure and a clearly expressed stratified structural profile are formed. With a sufficiently deep occurrence of soil ground waters the water regime of the river bed flood-plain soils depend upon surface wetting by atmospheric precipitation. At the middle and lower course of the river the river bed flood-plain has been cultivated and reclaimed for vegetable and forage-vegetable crop rotations.

The central-flood plain has a slightly undulating surface composed of clay loam and clay alluvium. Sod-meadow and meadow medium and fine clay loams under optimal conditions of wetting by surface and ground waters form the soils of this part. The soils of the central flood-plain are characterized by a higher content of humus and nutrients, a greater adsorption capacity, a stable granular structure, and, as a rule, a presence of gleying signs. The central flood-plain has also been partially cultivated, with a large part of the flood-plain continuing to remain as hay fields, and highly valuable meadows.

Meadow bog fine clay loams formed under excessive moisture conditions are wide-spread in the terrace flood-plain adjoining the first terrace above the flood-plain. A large part of this flood-plain is covered with inferior meadows, in the grass stand of which hair grass, meadow grass, reed grass, and other plants are predominant.

Soils in the Moscow River flood-plain possess, in most cases, a neutral or even weakly alkali reaction (pH of water suspension from 6. 1 to 7. 2-7. 3) and a high base saturation (calcium and magnesium from 11. 7-14. 5 to 36. 3-58. 6 meg per 100 g of soil).

Content of Humus, Total and Hydrolyzable Nitrogen in Moscow River Flood-Plain Soils

Optimal conditions of water-air and nutrient regimes in the river flood-plains are conducive to development of a grass vegetation and accumulation of organic matter in the soils. Contributing to this, too, is a periodic deposit of silt, rich in plant nutrients, and a neutral reaction indigeneous to the flood-plain soils under study.

Numerous analyses of the Moskvoretskaya

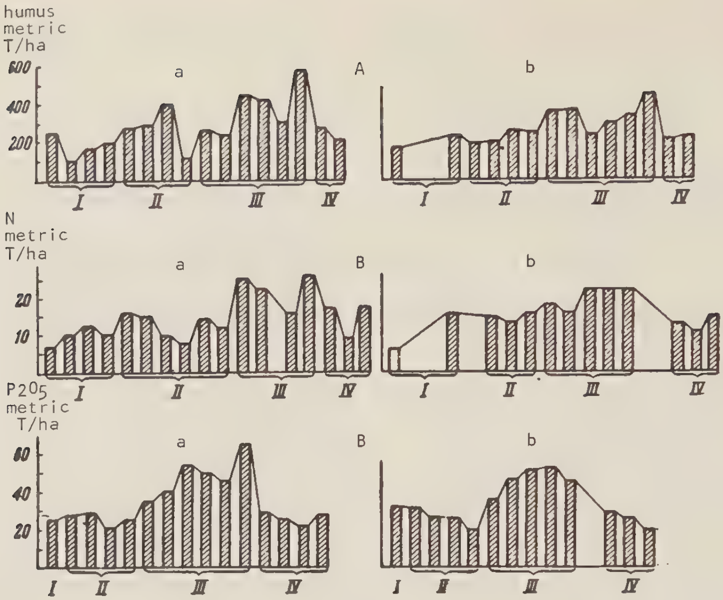


Fig. 1. - Contents of humus, nitrogen, phosphorus and potassium in the Moscow River flood-plain soils (expressed in metric tons/ha per weight of 0-100 cm layer of soil).

A - humus; B - nitrogen; C - phosphorus. a - along-the-river-side of flood-plain; b - central flood-plain. I - upper course; II. III. IV. - lower course.

flood-plain soils were made for humus content, and the humus contents were computed throughout the soil profile for various flood-plain segments. (Table 1 and Fig. 1-A).[1]

At the upper and middle course of the Moscow River (above Moscow) on flood-plain strips which have largely escaped the conditions of inundation and alluvialness, humus content throughout the soil profile along-the-river-side and central flood-plain varies between 2.2% and 2.7%.

At the lower course (on a flood-plain segment from Moscow to the village Ryblovo) humus content increases up to 2.8%-3.3% in sod, silty-sandy loam soils along-the-river-side flood-plain, and up to 2.4%-3.4% in sod, meadow, and meadow-medium and fine clay loam soils of the central-flood plain. The humus formation processes are expressed most intensively in soils of the Faustovskoye and Kolomenskoye expansions (near the river mouth) famed for their highly valuable meadows and subject to annual flooding by melted snows. Along with the vigorous development here of grass vegetation, a deposit of alluvium containing mixtures of organic residue and humus likewise favors humus accumulation in the soils of these expansions.

From analytical data the humus content in the soils of the Faustovskoye and Kolomenskoye expansions vary, on an average, between 4.0% and 5.5% which exceeds 2-2.5 times or more the humus content in soils of the higher flood-plain strips.

As a whole for the Moskvoretskaya flood-plain soils, we should note the higher rate of humus-formation processes, which is far from being indigeneous to non chernozem zone conditions. If humus contents in a meter layer of podzolic soils amount, on an average, to 102 metric tons/ha (1) then the humus contents in the soils for most of the Moscow River flood-plain strips examined (Fig. 1-A) equal 250-400 metric tons/ha. About one third of this content (in contrast to sod-podzolic soils) is concentrated in the top soil layer (0-20 cm); the remaining humus is distributed more or less evenly throughout the entire profile of flood-plain soil.

On flood-plain segments near the mouth of the Moscow River (the Faustovskoye and Kolomenskoye expansions) humus contents in the soils are so significant that they approach the humus content in the soils of the Chernozem group.

---

[1] In computing contents of humus, nitrogen, phosphorus and potassium, mean bulk densities were assumed with variations between 1.19 and 1.28 in sod, silty-sandy loam, and coarse clay loam soils and between 1.11 and 1.22 in meadow medium and fine clay loam soils.

Table 1

Humus content in Moscow River flood-plain soils, %

Locations of study	Mean depth, cm	Sod, silty-sandy loam, and coarse clay loam soils			Meadow, medium, and fine clay loam soils			Meadow and meadow bog fine clay loam soils		
		Along-the-river flood-plain			Central flood-plain			Along-the-terrace flood-plain		
		Mean	Range of variation	No. of profiles	Mean	Range of variation	No. of profiles	Mean	Range of variation	No. of profiles
Upper course[a]	0—24	2,1	1,2—2,6	4	2,4	1,2—2,5	2	—	—	—
	24—46	1,2	0,4—1,7	4	0,5	0,4—0,5	2	—	—	—
	46—68	0,4	0,3—0,5	4	0,3	0,1—0,7	2	—	—	—
	68—96	0,5	0,3—0,7	4	0,4	0,1—1,0	2	—	—	—
	96—125	0,5	0,2—1,0	4	0,5	—	2	—	—	—
Middle course[b]	0—24	2,0	1,9—2,1	2	2,7	2,6—2,6	2	2,6	1,5—3,7	2
	24—46	1,5	1,3—1,8	2	1,4	0,6—1,9	2	1,5	0,6—2,4	2
	46—68	1,4	1,4—1,4	2	1,2	0,7—1,9	2	1,3	1,1—1,4	2
	68—96	0,8	0,7—0,9	2	1,9	1,7—2,2	2	0,7	0,6—0,7	2
	96—125	0,8	0,8—0,9	2	1,8	1,8—2,1	2	0,6	0,5—0,6	2
Lower course[c]	0—24	3,3	1,4—5,0	5	3,4	1,8—5,8	5	3,9	—	1
	24—46	2,6	1,0—4,4	5	2,4	1,0—3,7	5	0,7	—	1
	46—68	1,8	0,8—2,5	5	1,6	0,9—2,0	5	0,3	—	1
	68—96	1,4	0,5—2,1	5	1,8	1,0—2,1	5	0,5	—	1
	96—125	0,7	0,4—1,6	5	1,4	0,7—2,1	5	—	—	1
Lower course[c] Faustovskoye expansion	0—24	4,5	3,2—6,1	5	5,5	4,5—6,9	3	5,2	3,9—6,9	3
	24—46	3,4	1,5—5,2	5	3,6	2,3—4,6	3	2,2	1,5—2,9	3
	46—68	2,4	1,6—3,7	5	2,7	2,1—3,1	3	2,8	2,3—5,2	3
	68—96	2,5	1,3—3,7	5	2,1	1,7—2,6	3	2,4	2,5—4,8	3
	96—125	1,7	1,1—2,4	4	1,9	1,5—2,1	3	—		—
Lower course[c] Kolomenskoye expansion	0—24	4,0	2,4—5,7	2	4,6	2,9—6,6	3			
	24—46	3,0	1,5—4,6	2	3,3	2,3—4,2	3			
	46—68	2,0	1,6—3,1	2	2,3	1,9—2,7	3			
	68—96	1,8	1,4—2,1	2	1,9	1,3—2,4	3			
	96—125	1,2	1,1—1,4	2	1,7	0,9—2,3	3			

a - above Zvenigorod;
b - from Zvenigorod to Moscow;
c - from Moscow to mouth of Moscow River.

Note: Comma represents decimal point

As we see from the data in Table 2, the total nitrogen content in the Moscow River flood-plain soils varies widely, which is due to the differences in the conditions of their formation on various flood-plain segments. Thus, in the sod silty-sandy loam and coarse clay loam soils along-the-river-side flood-plain the total nitrogen content in the plowed layer varies between 0.11% and 0.28% and in the meadow bog medium and fine clay loam soils of the central and terrace flood-plains between 0.11% and 0.36%-0.38%. From the upper reaches of the Moscow River to its mouth we note a definite tendency for total nitrogen content and its amount to increase together with an increase in these soils of the amounts of humus. Thus, for the flood-plain strips above Moscow (the middle and upper course) the amount of nitrogen in a 0-100 cm soil layer was 10.7 metric tons/ha (mean of 10 analyzed profiles), and 16 metric tons/ha for soils of the lower course of the river. In the latter instance, the amount of nitrogen in 18 of 26 profiles varied between 15 and 26 metric tons/ha, while in 10 cases the amounts ranged from 8 to 14 metric tons/ha per weight of a 1-meter layer of soil. The size of these accumulations becomes more appreciable if we recall that the amounts of nitrogen in the same layer of sod podzolic soils are, on an average, 6.6 metric tons/ha and in soils of the Chernozem group, 17-36 metric tons/ha (1).

By content of mineral nitrogen and easily

Table 2

Content of total and hydrolyzable nitrogen in Moscow River flood-plain soils

Locations of study	Mean depth, cm	Total N, %									Hydrolyzable N, mg/100g of soil					
		Sod silty-sandy loam and medium clay loam soils			Meadow medium and fine clay loam soils			Meadow and meadow bog fine clay loam soils			Sod silty-sandy loam and coarse clay loam soils			Meadow medium and fine clay loam soils		
		Along-the-river flood-plain			Central flood-plain			Along-the-terrace flood-plain			Along-the-river flood-plain			Central flood-plain		
		Mean	Range of variation	No. of profiles	Mean	Range of variation	No. of profiles	Mean	Range of variation	No. of profiles	Mean	Range of variation	No. of profiles	Mean	Range of variation	No. of profiles
Upper course[a]	0— 24	0,16	0,13—0,26	6	0,16	—	—	—	—	—	7,0	9,5—9,3	3	6,6	6,5—6,7	2
	24— 46	0,08	0,06—0,10	6	0,03	—	—	—	—	—	5,0	3,9—6,7	3	4,6	4,5—4,8	2
	46— 68	0,08	0,04—0,16	6	0,08	—	—	—	—	—	7,0	3,6—8,4	3	4,5	4,2—4,8	2
	68— 96	0,06	0,02—0,14	6	0,02	—	—	—	—	--	4,4	2,8—5,9	3	4,0	3,1—5,0	2
	96—125	0,08	0,02—0,16	6	0,01	—	—	—	—	—	4,6	1,7—8,1	3	3,6	2,5—4,8	2
Middle course[a]	0— 24	0,13	0,12—0,15	3	0,16	0,12—0,16	2	0,19	0,11—0,21	3	7,3	—	1	7,4	—	1
	24— 46	0,14	0,09—0,20	3	0,11	0,09—0,12	2	0,12	0,05—0,16	3	6,1	—	1	6,1	—	1
	46— 68	0,08	0,07—0,10	3	0,08	0,04—0,11	2	0,08	0,07—0,09	3	5,4	—	1	5,6	—	1
	68— 96	0,05	0,04—0,06	3	0,12	0,06—0,10	2	0,05	0,04—0,08	3	4,3	—	1	5,6	—	1
	96—125	0,06	0,03—0,07	3	0,10	0,05—0,11	2	0,07	0,04—0,11	3	3,6	—	1	4,8	—	1
Lower course[a]	0— 24	0,15	0,11—0,18	3	0,18	0,11—0,20	4	0,26	0,22—0,29	2	6,5	4,8—8,1	4	10,0	9,8—10,3	2
	24— 46	0,15	0,11—0,18	3	0,15	0,10—0,14	4	0,22	0,11—0,33	2	6,4	4,2—8,4	4	5,9	5,3— 6,5	2
	46— 68	0,10	0,08—0,13	3	0,10	0,07—0,13	4	0,21	0,14—0,22	2	5,9	3,4—7,3	4	4,5	4,1— 5,0	2
	68— 96	0,06	0,04—0,08	3	0,12	0,08—0,16	4	0,21	0,12—0,23	2	3,9	2,5—5,4	4	6,2	5,6— 6,8	2
	96—125	0,08	0,03—0,10	3	0,10	0,07—0,15	4	—	--	—	3,8	2,4—5,6	4	3,5	1,1— 5,9	2
Lower course, Faustovskoye expansion	0— 24	0,20	0,14—0,28	6	0,22	0,16—0,29	3	0,26	0,23—0,29	2	5,6	3,6—9,2	4	7,2	5,9—10,0	4
	24— 46	0,19	0,08—0,30	6	0,17	0,17—0,22	9	0,22	0,11—0,33	2	6,3	3,6—9,8	4	6,8	3,9— 9,4	4
	46— 68	0,14	0,09—0,20	6	0,17	0,12—0,19	9	0,21	0,02—0,39	2	5,2	3,4—7,8	4	6,1	2,8— 8,6	4
	68— 96	0,14	0,06—0,21	6	0,15	0,13—0,16	9	0,21	0,03—0,39	2	5,5	2,8—8,9	4	6,3	3,6— 5,8	4
	96—125	0,12	0,06—0,17	6	0,12	0,09—0,17	9	—	—	—	4,4	4,3—6,1	4	4,8	4,4— 5,6	4
Lower course Kolomenskoye expansion	0— 24	0,21	0,11—0,26	3	0,24	0,18—0,36	5	—	—	—	2,9	2,8—3,1	2	3,7	2,8— 5,9	4
	24— 46	0,14	0,08—0,20	3	0,17	0,15—0,31	5	—	—	—	2,3	2,2—2,5	2	4,5	2,8— 7,3	4
	46— 68	0,12	0,05—0,16	3	0,12	0,13—0,26	5	—	—	—	2,0	2,0—2,0	2	4,2	4,2— 4,2	4
	68— 96	0,11	0,10—0,12	3	0,10	0,08—0,18	5	—	—	—	1,9	1,7—2,2	2	3,5	2,8— 5,6	4
	96—125	0,07	0,05—0,09	3	0,10	0,08—0,17	5	—	—	—	2,4	2,2—7,6	2	4,4	3,4— 7,0	4

a - see footnote to Table 1.

Note: Comma represents decimal point

hydrolyzable nitrogen compounds, Moscow River flood-plain soils should be assigned to soils having a good supply of nitrogen (more than 6 mg N per 100 g of soil). However, for vegetables requiring a large amount of nitrogen, the criteria for nitrogen supply to soils (according to the method of I. V. Tyurin and M. M. Kononova) should be increased. In our experiments in the Moscow and Oka River flood-plains (5, 6, 7), soils with an easily hydrolyzable nitrogen content of 10-12 mg per 100 grams respond well to the addition of nitrogen. Cabbage yield increased 182-251 cntr/ha (when the yield from PK was 582 and 519 cntr/ha, respectively) and table beets 40-80 cntr/ha (when the yield from PK was 350 and 304 cntr/ha).

Content and Amounts of Total Phosphorus and Phosphorus Available to Plants in Moscow River Flood-Plain Soils

The soil of the Moscow River basin (with a total area of 17, 640 km²) consists, for the most part, of sod-podzolic soils with a low content of total phosphorus, usually not exceeding 0. 06%-0. 11% P_2O_5. Soils having a high phosphorus supply are formed in the Moscow River flood-plain. As computations have shown, total phosphorus contents in a 1-meter layer of river bed flood-plain sod soils and of sod meadow, meadow, and meadow bog soils of the central and terrace flood-plains are, on an average, 20-35 metric tons/ha, P_2O_5, attaining in the regions of the lower course of the Moscow River 45-65 metric tons/ha, P_2O_5 (Fig. 1-B). These phosphorus amounts are unusually high not only for non-chernozem zone soils but also, generally for soils of higher fertility.

Throughout the Moscow River flood-plain the content of total phosphorus in the soils (in comparison with humus and nitrogen) changes, increasing from 0. 22%-0. 24% P_2O_5 in regions of the upper and middle course to 0. 49%-0. 52% in regions of the lower course. Maximum phosphorus content (with variations within limits of 0. 33%-0. 58% P_2O_5) is noted in the soils of the Faustovskoye and Kolomenskoye expansions, which are subject to annual and comparatively more extensive flooding by spring high waters accompanied by a deposit of thick alluvium (Table 3). The alluvium deposit is the main reason for the formation in the Moscow River flood-plain of soils with a high phosphorus content. As analyses have shown, the content of total phosphorus in alluvium varies between 0. 66% and 0. 72% P_2O_5, attaining in alluvium on certain strips of flood plain 0. 90%-1. 14% P_2O_5. The question naturally arises as to the origins of this phosphorus, especially if we take into account the fact that the soil of the Moscow River basin is made up, for the most part, of sod-podzolic soils deficient in phosphorus.

Deserving attention in this sense is the statement by Dobrovol'skiy and Tyuryukanov (2, 3, 6), who regard as the main source of phosphorus being deposited in the alluvium and soils of the Moskvoretskaya flood-plain the bedrocks of the Jurassic Period, outcrops of which were evident everywhere on the surface n the Moskovskaya Oblast'. Well-known, for example, are the Voskresenskiye and Yegor'yevskiye Jurassic phosphorites used as raw material for producing phosphorous fertilizers. As a result of the erosion, weathering, and dissolving processes, the phosphorus of the native rocks is washed away. Together with spring high waters it descends onto the flood-plain, settling here in the form of various calcium phosphate salts or iron and aluminum phosphates.

On the tilled strips along-the-river and central flood-plains a replenishment of the soil with phosphorus also occurs because of phosphorus fertilizers being applied in large amounts for vegetables and potatoes.

Drainage waters flowing into the Moscow River in the course of a year may affect somewhat the chemical composition of flood-plain soils and, in particular, their phosphorus content. However, this influence may occur only during spring floods, when the surface layers of the flood-plain come into direct contact with the spring high waters and the substances dissolved in them. During the spring flood of 1958 samples of spring high water were taken at 6 points (above and below Moscow) and analyzed for phosphorus content. Noticeable quantities of phosphorus were detected only in suspended muddy particles with a complete absence of phosphorus in the dissolved state. In addition, the phosphorus content in the alluvium of all 6 samples was approximately the same.

Predominant in the group composition of phosphates, alluvium, and soils of the Moscow River flood-plain are mineral phosphorus compounds which make up 80%-90% of the total phosphorus contents. A wide ratio between organic and mineral forms of phosphorus is typical of the entire profile of flood-plain soil, when there is a very even distribution of organic phosphorus among individual horizons (4).

In 134 of 169 mixed samples of flood-plain soils analyzed, the content of acetic-soluble phosphorus (after the method of F. V. Chirikov) was more than 10 mg per 100 g of soil (with variations between 10 and 30 mg); in 18 samples this content varied between 5 and 10 mg, and only in 17 samples was it less than 5 mg P_2O_5 per 100 g of soil. In 74 soil samples out of 103 the content of P_2O_5 extracted by an acetate buffer mixture (modification of D. M. Shtrausberg) was more than 3 mg P_2O_5 per 100 g of soil, which indicates the excellent and average supply of available forms of phosphates to soils. A high content of available forms of phosphates is widespread in the flood-plain soils at a great depth (Table 3).

Throughout the flood-plain large quantities of phosphates readily available to crops are found in the soils of the lower course of the Moscow River (below Moscow, Table 3). From the river to the terrace flood-plain the phosphorus availability of flood-plain soils decreases. The smallest amounts are detected in fine textured meadow bog soils of the along-the-terrace flood-plain and are due to the fixation of phosphorus in the less soluble iron and aluminum phosphates.

The phosphorus of flood-plain soils is readily available to crops. In field experiments on soils of the Moskvoretskaya and Okskaya flood-plains, addition of phosphorus fertilizers was not accompanied, as a rule, by yield increases (4, 5).

Table 3

Content of total and available phosphorus in Moscow River flood-plain soils

Locations of study	Mean depth, cm	Total content P_2O_5, %									Available phosphorus (in 0. 5n CH_3COOH), mg P_2O_5 per 100 g of soil					
		Sod silty-sandy loam coarse clay loam stratified soils			Meadow medium and fine clay loam soils			Meadow and meadow bog fine clay loam soils			Sod silty-sandy loam stratified soils			Meadow medium and fine clay loam soils		
		Along-the-river flood-plain			Central flood-plain			Along-the-terrace flood-plain			Along-the-river flood-plain			Central flood-plain		
		Mean	Range of variation	No. of profiles	Mean	Range of variation	No. of profiles	Mean	Range of variation	No. of profiles	Mean	Range of variation	No. of profiles	Mean	Range of variation	No. of profiles
Middle course[b]	0— 24	0,22	—	1	0,24	—	1	0,18	—	1	9	9	4	7	4—13	3
	24— 46	0,20	—	1	0,30	—	1	0,18	—	1	7	6— 8	4	4	1— 8	3
	46— 68	0,24	—	1	0,30	—	1	0,10	—	1	6	5— 9	4	4	2— 8	3
	68— 96	0,21	—	1	0,26	—	1	0,11	—	1	6	3—10	4	5	2—11	3
	96—125	0,16	—	1	0,29	—	1	0,11	—	1	6	5— 9	4	7	3—14	3
Lower course[a]	0— 24	0,25	0,18--0,30	3	0,25	0,20—0,25	3	0,30	—	1	27	20—33	5	21	15—30	6
	24— 46	0,22	0,19—0,23	3	0,29	0,20—0,36	3	0,22	—	1	21	13—29	5	15	6—40	6
	46— 68	0,17	0,14—0,21	3	0,22	0,17—0,26	3	0,14	—	1	21	12—27	5	11	4—25	6
	68— 96	0,19	0,17—0,22	3	0,24	0,22—0,26	3	0,30	—	1	20	17—30	5	8	4—14	6
	96—125	0,23	0,17—0,28	3	0,26	0,22—0,31	3	—	—	—	20	11—28	5	9	6—18	6
Lower course, Faustovskoye expansion	0— 24	0,52	0,33—0,68	4	0,49	0,41—0,58	4	0,31	—	1	19	11—25	4	22	17—28	2
	24— 46	0,43	0,30—0,54	4	0,40	0,35—0,46	4	0,23	—	1	20	15—26	4	16	13—18	2
	46— 68	0,34	0,26—0,44	4	0,44	0,37—0,56	4	0,18	—	1	18	12—20	4	16	14—18	2
	68— 96	0,38	0,27—0,43	4	0,40	0,31—0,44	4	0,24	—	1	15	13—17	4	16	11—21	2
	96—125	0,29	0,28—0,29	4	0,35	0,28—0,44	4	—	—	—	14	13—16	4	20	—	—
Lower course, Kolomenskoye expansion	0— 24	0,34	0,25—0,39	5	0,29	0.20—0,33	3	0,26	—	1	19	17—22	3	21	—	1
	24— 46	0,27	0,20—0,31	5	0,19	0,16—0,24	3	0,18	—	1	17	16—18	3	18	—	1
	46— 68	0,19	0,13—0,22	5	0,17	0,15—0,19	3	0,16	—	1	16	15—18	3	16	—	1
	68— 96	0,23	0,13—0,27	5	0,21	0,18—0,23	3	0,15	—	1	19	15—23	3	22	—	1
	96—125	0,21	0,16—0,25	5	0,20	0,18—0,22	3	—	—	—	17	16—19	3	15	—	1

a - see footnote to Table 1.

Note: Comma represents decimal point

Table 4

Content of total and exchangeable potassium in Moscow River flood-plain soils

Locations of study	Mean depth, cm	Total content K_2O_5, %									Avail potas mg K_2O/100 g of soil					
		Sod silty-sandy loam and coarse clay loam soils			Meadow medium and fine clay loam soils			Meadow and meadow bog fine clay loam soils			Sod silty-sandy loam and coarse clay loam soils			Meadow medium and fine clay loam soils		
		Along-the-river flood-plain			Central zone			Along-the-terrace flood-plain			Along-the-river flood-plain			Central flood-plain		
		Mean	Range of variation	No. of profiles	Mean	Range of variation	No. of profiles	Mean	Range of variation	No. of profiles	Mean	Range of variation	No. of profiles	Mean	Range of variation	No. of profiles
Middle course[a]	0—24	1,78	1,62—1,95	2	1,91	1,86—1,96	2	1,77	1,65—1,89	2	7	6—9	11	8	5—12	6
	24—46	1,85	1,74—1,96	2	1,92	1,94—1,88	2	1,81	1,62—2,0	2	6	5—7	11	6	4—7	6
	46—68	1,77	1,74—1,80	2	1,44	1,00—1,89	2	1,96	1,89—2,03	2	5	3—6	11	6	3—10	6
	68—96	1,59	1,33—1,84	2	1,45	0,91—1,98	2	2,01	1,94—2,08	2	6	3—11	11	7	5—10	6
	96—125	1,31	1,30—1,33	2	1,98	0,92—1,98	2	2,02	2,01—2,03	2	6	3—11	11	8	6—11	6
Lower course[a]	0—24	1,82	1,79—1,86	2	1,44	1,31—1,56	2	1,88	—	1	9	7—14	6	10	10—11	4
	24—46	2,05	1,93—2,18	2	2,20	1,70—2,70	2	2,06	—	1	7	6—10	6	8	5—9	4
	46—68	1,82	1,60—2,04	2	1,72	1,52—2,04	2	1,33	—	1	6	4—8	6	8	7—9	4
	68—96	1,62	1,57—1,67	2	1,92	1,86—1,98	2	1,52	—	1	6	5—9	6	8	7—9	4
	96—125	1,56	1,54—1,58	2	1,78	—	1	1,52	—	1	5	4—6	6	8	8—9	4
Lower course, Faustovskoye expansion	0—24	1,69	—	1	1,88	1,77—2,06	3	1,70	—	1	13	8—19	6	11	8—13	4
	24—46	1,67	—	1	1,96	1,79—2,06	3	1,89	—	1	9	6—12	6	10	9—12	4
	46—68	1,67	—	1	1,92	1,81—2,10	3	2,08	—	1	8	7—11	6	10	10—11	4
	68—96	1,62	—	1	1,83	1,74—1,88	3	1,86	—	1	9	7—12	6	10	8—13	4
	96—125	1,62	—	1	1,85	1,81—1,89	3	1,86	—	1	6	8—10	6	9	6—11	4
Lower course, Kolomenskoye expansion	0—24	1,50	1,38—1,62	2	1,57	—	1	1,70	1,57—1,84	2	8	7—10	5	9	7—11	3
	24—46	1,45	1,28—1,52	2	1,71	—	1	1,87	1,79—1,96	2	6	5—6	5	7	5—9	3
	46—68	1,32	1,15—1,50	2	1,88	—	1	1,58	1,31—1,86	2	6	4—8	5	9	9—9	3
	68—96	1,40	1,29—1,51	2	1,96	—	1	1,42	1,14—1,70	2	6	3—7	5	9	9—9	3
	96—125	1,50	1,50	1	2,06	—	1	1,70	1,70	2	6	3—8	5	9	9—9	3

a - See footnote in Table 1

Note: Comma represents decimal point

Content and Amounts of Total and Exchangeable Potassium in Moscow River Flood-Plain Soils

Potassium compounds in soils are, primarily, minerals from a group of feldspars, the potassium of which is practically unavailable to crops. A smaller portion of soil potassium is found in the mica mineral group (muscovite, biotite) and is part of glauconite and nepheline, which readily relinquish their potassium in exchange for other cations. The total amounts of potassium provide, therefore, only a general picture of potassium reserves but do not as yet describe the conditions required for potassium nourishment of crops in these soils.

From analytical data the content of total potassium in the plowed sod silty sandy loam and coarse clay loam soils along-the-river flood-plains (according to length of flood-plain) varies between 1. 50% and 1. 82% and between 1. 44% and 1. 91% in the meadow and meadow bog soils of the central and terrace flood plains (Table 4). These amounts are considerably smaller than those which are usually found in sod-podzolic soils (2. 3%-2. 5%) of the non chernozem zone.

The principal source of potassium supply to crops is assumed to be the adsorbed or exchangeable potassium of the soil. Of all available methods for determining exchangeable potassium, the Maslova method, based on treating soil with 1. 0 n solution of ammonium acetate, displaces potassium more completely. From the flood-plain soils this extract (with a soil solution ratio 1:10, hourly shaking and spectral determination of K_2O in solutions tested) recovers 70%-100% adsorbed potassium. On the whole, about 300 mixed samples of flood-plain soils (from plowed layers) and over 200 samples from profiles throughout the genetic horizons were analyzed using Maslova's method.

In an overwhelming number of cases the content of exchangeable potassium was not more than 5-10 mg K_2O per 100 g of soil (with variations between 3-5 and 13-14 mg) which indicates an extremely low level of potassium supply in the flood-plain soils studied. Quantitatively, the total and exchangeable potassium have been distributed more or less evenly throughout the entire profile of flood plain soil, when there is no potassium migration from the upper into the lower-lying horizons (Table 4).

Thus, against a background of a generally higher fertility we find a shortage of potassium in the soils of the Moscow River flood-plain.

Conclusions

1. The fertility of Moscow River flood-plain soils increases gradually from the upper to the lower course and perpendicular from the river to the terrace flood-plain:

a) on flood-plain strips of the upper and middle course (above Moscow) humus content in the soils along the river flood-plain is 2. 0%-2. 1% attaining 3. 0%-3. 4% at the lower course; correspondingly, in soils of the central flood-plain it increases from 2. 2%-2. 7% to 4. 5%-5. 5% and in soils along-the-terrace flood-plain from 2. 6% to 3. 9%-5. 2%.

b) The content of total nitrogen increases, respectively, from 0. 13%-0. 16% to 0. 20%-0. 21% in soils along-the-river flood-plain; from 0. 16% to 0. 22%-0. 24% in soils of the central flood-plains, and from 0. 19%-0. 26% in soils along-the-terrace flood-plain.

c) The content of total phosphorus in soils of the lower course is 0. 34%-0. 52% P_2O_5 along-the-river flood-plain (in place of 0. 22% at the upper course) and, correspondingly, 0. 29%-0. 49% and 0. 26%-0. 31% P_2O_5 in soils of the central and along-terrace flood-plains instead of 0. 18% and 0. 24% P_2O_5 on flood-plain strips of the upper course.

2. At the lower course of the Moscow River where thick silty sandy loam and coarse clay loam alluvium rich in plant nutrients is deposited annually along-the-river flood-plain, the total amounts of humus, nitrogen, phosphorus, and potassium in the soils along-the-river flood-plain frequently approach in quantity these amounts in the soils of the central and terrace flood-plain.

3. While there is relative abundance of calcium and magnesium cations, the soils of the Moscow River flood-plain are deficient in exchangeable potassium.

4. The soils of the Moscow River flood-plain, especially on segments of the lower course ((below Moscow), have greater amounts of phosphates available to crops.

5. The nitrogen supply for Moscow River flood-plain soils should be studied, taking into account the biological characteristics of the crops being cultivated; application of nitrogen fertilizers for crops with a lengthy vegetative period will somewhat increase crop yield.

Received January 18, 1960

BIBLIOGRAPHY

1. BOLOTINA, N. I. 1947. Humus and nitrogen contents in the principal soil groups of the USSR. Pochvovedeniye, No. 5.
2. DOBROVOL'SKIY, G. V. 1957. The problems of the theory of soil formation in river flood-plains of the forest zone. Vestnik Moskovskogo universiteta No. 1.
3. DOBROVOL'SKIY, G. V. 1958. Classifying flood-plain soils of the forest zone. Pochvovedeniye, No. 8.
4. KORABLEVA, L. I., and Z. A. PROKHOROVA. 1953. Fertilizer effectiveness on flood-plain soils. Pochvovedeniye, No. 10.
5. KORABLEVA, L. I. 1959. Nutrient regime and fertilizer effectiveness on flood-plain plantings. Udobreniye i urozhay No. 5.
6. TYURYUKANOV, A. N. 1957. Characteristics and factors determining the chemical composition of soil ground waters of the flood-plain. Pochvovedeniye, No. 9.

DESALINIZATION CONDITION OF MEADOW SOILS AT THE MIDDLE COURSE OF THE AMU DAR'YA RIVER

I. S. RABOCHEV, Institute for Soil Science and Reclamation of Sands, Academy of Sciences, Turkmenskaya SSR

In desalinizing and preventing salinization of soils we must analyze together the problems of the water and salt regime of an area. The early idea that only the initial stage of the soil-water regime had to be regulated by cutting down water supply and intensifying ground-water transpiration has brought us to only a partial realization of the principles of melioration. Recommendations for strict standardization of leaching under non-drainage conditions and curtailment of leaching in every possible way were aimed at preventing the rise of ground waters. However, when the water supply is inadequate, the salts are flushed to shallow depths and rise comparatively rapidly into the top soil layers which lessens the effect of leaching. The idea that mere control of the water balance of an area is of prime importance in reclaiming salinized soils is tantamount, generally, to rejection of drainage (14).

Various types of salt profiles in soil and in the water-bearing layer of soil materials are formed under the influence of vertical and horizontal salt movement. We can distinguish the following stages in the salt regime of soil according to types of salt profiles and the processes occurring in the soils: a) — desalinization; b) — intermittent desalinization — seasonal salinization; c) — salt accumulation (salinization).

The desalinization stage takes place in weakly salinized soils with a solid residue content $< 0.5\%$, Cl — 0.02% and SO_4 — 0.05% when the fresh ground waters are at a depth greater than 2 m. A favorable salt regime in these soils which are the most valuable part of the land reserve of the Amu Dar'ya River Valley is preserved by applying a high level of agricultural technology to irrigated crops.

The stage of intermittent desalinization — seasonal salinization — is observed in the soils inadequately leached of salts. These are principally the medium and strongly salinized soils with a solid residue content $>1\%$-2%, Cl 0.05%-0.10%, SO_4 0.10%-0.3% when the more severely mineralized ground waters are at a depth of 1-2 m.

The continuous salt accumulation or salinization stage of soils occurs in the non irrigated solonchaks when the stagnant severely mineralized ground waters are at a depth up to 1-2 m.

The stages and types of salt regime in soils are dynamic and depend upon the methods of land utilization. In studies by Kostyakov (3), Rozov, (12), Malygin (4, 5), Makridin (6), Kovda (2), Rozanov (7), and other investigators complex salt accumulation processes are analyzed considering the geomorphological and histological conditions associated with the system of various land improvements.

Salt is accumulated in the soil whenever salt intake is greater than salt loss. especially if upward flow of water prevails over downward flow.

The types of soil profiles in meadow soils most often found are shown in Figure 1. In a well-leached soil in the desalinization stage, a small quantity of salt is distributed evenly throughout the entire profile. But even in this soil, as the result of capillary salt removal, we observe an increase in salt content in the fall as opposed to the spring. In moderately salinized soil, assigned to the intermittent desalinization — salinization stage, intensive salt accumulation takes place. However, in the strongly salinized soil, there is a considerable seasonal accumulation of salt owing to the movement of a large quantity of readily available salt into the top layers.

Consequently, in irrigated soils the types and character of the salt regime are determined by soil utilization conditions in agriculture. In solonchaks, as the result of predominant unilateral upward flows of water, the magnitude of which is 10-13 times total precipitation and water vapor[1] condensation, systematic accumulation of salts takes place in the upper horizons (10). Here occurs a natural redistribution of salt and capillary flows owing to a significant drop in the concentration of salt solutions between the top and bottom layers of soils.

---

[1] Annual total atmospheric precipitation and water vapor condensation is 480 m^3/ha, while evaporation by fallow lands and solonchaks is 4.5-6.2 thousand m^3/ha.

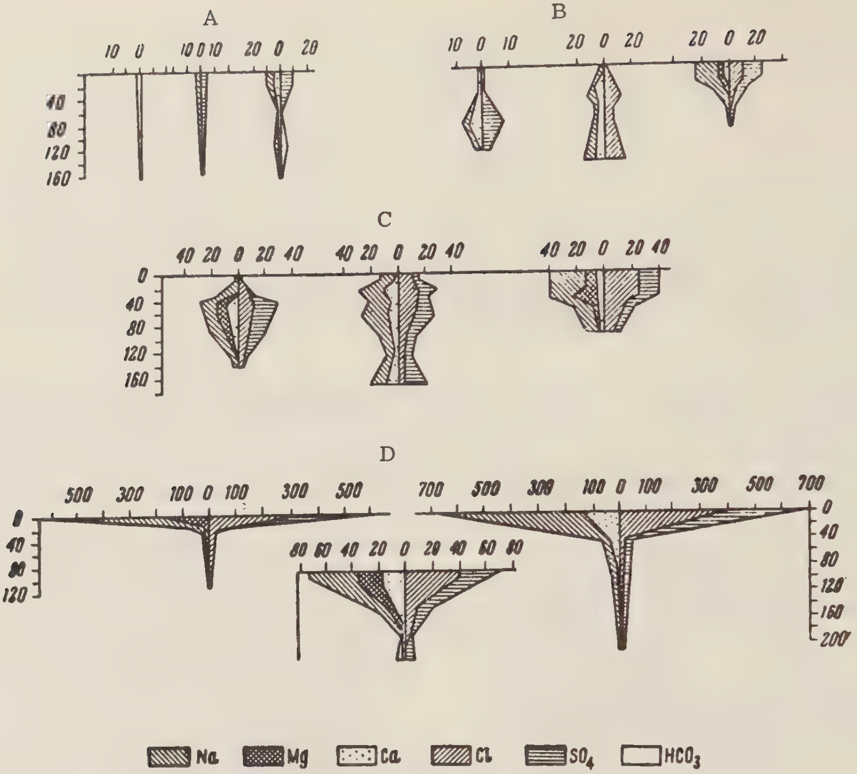


Fig. 1. - Types of salt profiles.

A - weak salinization, stage of desalinization; B - average salinization, stage of seasonal desalinization - salinization; C - severe salinization, stage of seasonal desalinization - salinization; D - solonchak.

If we utilize lands properly, irrespective of initial state of salinization, we may be able to desalinize all soil classes to a level of stability, when the total salt in the soil and ground waters is not more than 0.1%-0.3%. In meadow soils this is achieved by leaching to drainage, combined with a high level of scientific agricultural practices.

To define more precisely the effect of irrigation on salt redistribution in soil in a 10-20 m water bearing soil layer on part of the Amu Dar'ya river valley, we conducted detailed studies of the salt composition under irrigated and nonirrigated conditions. For this purpose holes were bored on each block studied — one bore hole on an irrigated strip and another 200-300 m from it on a solonchak strip.

In the ground water of solonchaks in a 12-16 m soil layer the dry residue content is 10-12 g/liter, while at a depth of 24 meters dry residue content is 21 g/liter (Figs. 2, 3).

The data on the analysis of ground waters by a layer at a depth of 20-25 meters reveals not only the complex but also the specific nature of salt accumulation on the middle course of the Amu Dar'ya. Absolute salt accumulation values in the upper horizons beneath solonchaks (to 20-30 g/liter) are evidence of extensive salt accumulation as the result of vertical salt exchange and redistribution among irrigated and nonirrigated areas. Large quantities of salt in the lower-lying layers (as well as to 20-30 g/liter) obviously owe their origin over a long geological period of time to diffusion phenomena and vertical displacement of salts from the deep layers containing salt accumulations and salt domes of marine sedimentary origin.

Irrigation sharply alters the natural salt profile of soils: in the aeration zone of cultivated fields the solid residue content is 2-5 g/liter, in a 3-11 m layer 1-2 g/liter and, deeper, in a 12-20 m, layer, 3-9 g/liter.

Table 1 shows mineralized ground water in a 10 meter layer, according to data from borings laid out on irrigated and solonchak plots.

Placing irrigation waters leads to decreasing salt concentration and salt displacement into the deep layers. This is illustrated by special experiments wherein during one season the changes in the salt profiles formed under natural conditions over a long period, were reproduced. Experiments on soil desalinization during rice

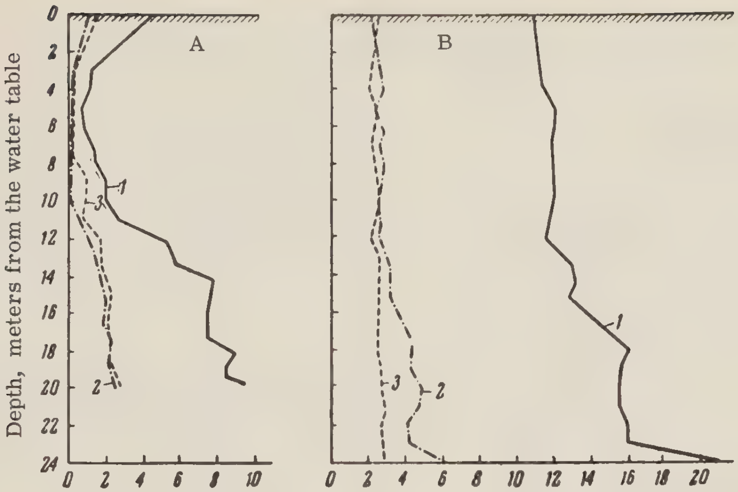


Fig. 2. - Ground-water mineralization from bore holes, in g/liter. Chardzhouskaya Experimental Station.

A - irrigated field; B - solonchak; 1 - solid residue; 2 - chloride ion; 3 - sulfate ion.

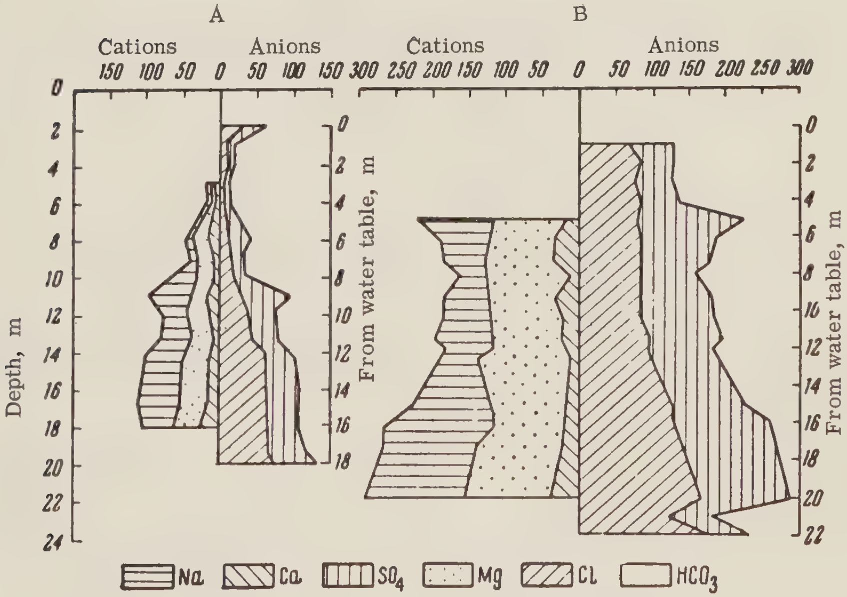


Fig. 3. - Salt content in ground waters.

A - irrigated plot; B - solonchak

ultivation conducted by the Chardzhouskaya xperimental Station have shown (Table 2) that fluenced by leaching even under nondrainage onditions the soil and ground waters were de-alinized in the layer below 5 m.

In a similar experiment conducted on a drain-ge plot at the same station, 37.5 thousand m^3/a of water (Table 3) were used without dis-arding water in growing rice.

Experiments have shown that irrigation can bring about decreases in salt contents in a 5-10 m soil layer and even in deeper layers. At the same time, under certain specific conditions, salts rise into the upper horizons when influenced by vertical and horizontal salt exchange.

Barren and idle lands, represented by fallow fields, abandoned lands, and solonchaks, play an important role in the redistribution and

Table 1

Mineralized ground water, g/liter

Distance fr. Amu Dar'ya River, km	Soils	Total salt	HCO_3 (total)	Cl	SO_4
2	Irrigated soils	1,85	0,239	0,524	0,415
	Solonchak soils	7,25	0,205	2,055	2,033
5	Irrigated soils	2,57	0,196	0,434	0,708
	Solonchak soils	21,10	0,264	7,684	0,846
8	Irrigated soils	2,15	0,143	0,485	0,563
	Solonchak soils	7,97	0,285	2,186	2,339
12	Irrigated soils	3,98	0,197	0,831	0,705
	Solonchak soils	8,25	0,156	1,971	1,555

Note: Comma represents decimal point.

Table 2

Chloride ion content in ground water, in g/liter before and after rice planting

Depth, m	Before reclamation October 20, 1946	After reclamation October 19, 1947	Decrease	
			Absolute	%
1,0—1,5	2,978	0,297	2,681	90,1
1,5—2,0	2,232	0,424	1,308	81,0
2,0—3,0	3,517	0,424	3,093	88,0
3,0—4,0	1,480	0,637	0,843	57,0
4,0—5,0	1,711	0,772	0,989	57,8
Mean in a 1-5 m layer	2,384	0,501	1,883	79,0

Note: Comma represents decimal point.

Table 3

Effect of rice planting on ground water desalinization in a 10-meter layer (bore-hole 4a, 1958)

Depth, meters	Dry residue, g/liter			Chloride-ion, g/liter		
	Before reclamation	After rice planting	%	Before reclamation	After rice planting	%
2,7— 3,7	11,090	4,065	36,6	2,402	0,354	14,9
3,7— 4,7	10,880	4,275	39,4	2,408	0,359	14,9
5,0— 5,3	9,525	4,850	51,2	1,890	0,359	19,0
5,3— 6,4	9,000	4,860	54,0	1,770	0,634	35,7
6,6— 7,7	9,000	4,876	54,2	1,730	0,782	45,2
8,0— 9,6	9,250	7,022	75,8	1,810	1,378	76,0
9,7—10,0	9,880	7,500	75,0	1,810	1,575	87,0
10,0—10,2	9,880	7,840	79,5	1,810	1,575	87,0

Note: Comma represents decimal point.

accumulation of soil salts in runoff regions and regions without artificial drainage. The salts removed from cultivated soils by irrigation water are forced back onto abandoned lands, which under such conditions are, after Malygin's (5) definition, "dry drainage." However, the importance of dry drainage in controlling the water salt regime is not always identical.

When there is considerable absolute salt accumulation the evaporation coefficient is sharply reduced and the free capacity of soil materials diminished. Consequently, it is not always possible to control the water and salt regimes of irrigated lands due to the low coefficient of land utilization (CLU). We shall offer as an example two regions with identical soils, identical size areas and agricultural structure, but a different CLU (Table 4).

In the Chardzhouskiy region where the CLU is comparatively high, irrigated lands cover large areas. The salt regime of the soils is influenced by water supply and the over-all complex of land-improvement practices being carried out on the fields. In addition, large irrigated areas come into contact relatively less with solonchaks. These solonchaks are the source of horizontal salt movement as a result of convective, diffusional, and other forms of salt movement.

The evaporation in soil is considerably weakened as the result of excessive saturation by salts. Also, the capacity for absorbing percolated waters and waters under pressure is lowered; consequently, the ground waters of solonchaks evaporate less strongly. The level of ground waters under such conditions is lowered primarily because of spreading, which is intensified as a result of the high specific gravity of the strongly mineralized waters.

Convective salt movement developed under such conditions leads to the intensification of the processes of recurring salt accumulation in the irrigated soils, especially those bordering the solonchaks. Basically, this also explains the presence of a higher specific gravity of more strongly salinized soils in the Deynauskiy region, as compared with those in the Chardzhouskiy region.

Another task of soil melioration along with application of leaching, drainage and scientific agricultural practices, is the prevention of salt from entering irrigated soils from non-irrigated soils. Horizontal salt movement (convective, diffusional, etc.), can be checked by creating a difference in drops of ground water level. As a result of (leaching) and vegetative irrigation the salts are flushed deeper, and the difference in drops of ground water level checks the lateral movement of salt solutions onto the fields.

The principal objective of land-improvement practices within the next few years will be to desalinize roughtly a 5-meter soil layer and ground water. Later on, in order to guarantee a stable desalinization of the area it will become necessary to desalinize layers 7-10 meters deep. Most specialists in land reclamation and soil scientists such as Rabochev (8, 9, 10), Fedorov (13), Morozov (7), Rozanov (11), Yegorov (1), and others, have arrived at this conclusion.

From rough calculations (Table 5) it is believed that in order to desalinize a 5-meter soil layer of the Chardzhouskiy Oasis (Sayat-Deynau) we will have to remove from irrigated soils about 600 metric tons of salt. Likewise, from fallow fields and abandoned lands, if they are reclaimed, about 1,700 metric tons of salt from each hectare will have to be removed.

We will have to remove from the entire area (56.5 thousand hectares of moderately and strongly salinized soils and 17.3 thousand hectares of reclaimable solonchaks) about 64 million metric tons of salt from a 5-meter soil layer and 70 million metric tons from a 10-meter soil layer. As the experiment shows, roughly half of the salt content is submerged in the deep soil layers.

According to a project of the Turkmenskoye State Institute for Planning Water Economy (TURKMENGIPROVODKHOZ) drainage flow is about 150 million m³ per year. When water mineralization is 10 g/liter, the annual salt removed will be 1.5 million metric tons, or 15 metric tons for 1 hectare of the whole area. More than 20 years will be required by such flow to remove 30-35 million metric tons of salt from the Chardzhouskiy Oasis. At present the amount of drainage flow is not more than 50-60 million m³ while salt removal is 0.5-0.7 million metric tons per year. Salt is presently being removed almost one and one-half times faster than the amount of salt entering with irrigation waters, (flow in the

Table 4

Values of coefficient land utilization (CLU) in the redistribution of soil salts in old irrigated regions

Regions	Total areas thous. of hectares	CLU	Specific weight of soils by salinity, %				Depth of ground waters, m		
			Non-salinized and weakly salinized soils	Moder. and strongly salinized soils	Solonchaks	Unsuitable lands	Nov. - March	April-Oct.	For a year
Chardzhouskiy	24,5	0,53	46,5	31,4	19,3	2,8	2,12	1,35	1,67
Deynauskiy	26,0	0,35	5,3	65,8	26,6	2,3	2,03	1,56	1,79

Note: Comma represents decimal point.

Table 5

Computations of removing salts contained in a 5-meter soil layer of the Chardzhouskiy Oasis

Indicators	Unit of measurement	Soils		
		Non-salinized and weakly salinized	Moderately and strongly salinized	Solonchaks
Area of oasis	Thous. of hectares	30,0	56,5	27,7
Salt content in soil	%	0,3	2,0	5,0
	m t/ha	105	580	1125
In ground water	g/l	2,5	9,0	31,0
	m t/ha	56	202	697
In soil and water	m t/ha	161.	782	1822
Subject to removal	"	—	621	1661
	millions of tons	—	35,0	28,7

Note: Comma represents decimal point.

oasis is 0. 8-1. 0 milliard m³, water mineralization is 0. 4-0. 5 g/liter). Thus, applying drainage prevents further salt accumulation. Drainage acts most effectively on the desalinization of lands having a relatively high drainage coefficient resulting from excellent conditions of underground flow.

To intensify salt removal from the oasis and to accelerate soil desalinization we must increase drainage flow by enlarging the drainage collector network and by extending the period of its operation.

We can increase the removal of salt with water by fall and winter flow, by which the operational period of the drainage network will be lengthened 1. 5-2 times.

Conclusions

1. Soils with a solid residue content of 0. 1%-0. 3%, as in ground water, are characterized by a stage of desalinization. To preserve this state of soil, we must prevent salt accumulation in the ground waters.

Intermittent, seasonal desalinization and salinization occur in soils insufficiently leached of salts; in the profile and ground waters of these soils the solid residue content is equal to 1%-2%. Desalinization processes will take place in soils after the soil and ground waters have been desalinized to a point where the solid residue content is 0. 3%-0. 5% and the land utilized for future crops. The soil salinization stage is typical of the nonirrigated fallow fields, abandoned lands, and solonchaks where the processes of removing salt from ground waters to soil horizons take place.

2. Irrigation causes the salt to submerge to a depth of 5-10 meters and more. In a 10-meter layer of irrigated soils, the solid residue is 1. 85-3. 98 g/liter; in solonchak-like soils it is 7. 25-21. 1 g/liter, or 4-8 times greater. By increasing the water supply during one or two seasons, we can desalinize a 5-10 meter soil layer which will preclude the need of annual leaching.

3. High salinity leads to a decrease in the free capacity and evaporation capacity of soils. Under such conditions it is impossible to do without drainage even when the coefficient of land utilization (CLU) is low, of the order of 0. 3-0. 4.

4. To eliminate convective flows of salt from solonchaks to irrigated lands we must create as large as possible drops in the horizons of ground waters. This is done by fall-winter leaching and by removing ground waters not only from irrigated fields but from solonchak-like massifs.

5. Desalinization, first of a 5-meter layer and then of a 7 to 10 meter layer of soil and ground waters, is part of the task of reclaiming salinized soils under the present-day level of science and technology.

The creation of a meadow-process soil formation and desalinized ground waters will eliminate repeated salinization and the need of annual leaching.

Received June 14, 1960

BIBLIOGRAPHY

1. YEGOROV, V. V. 1959. Soil formation and requirements for irrigation improvements in the deltas of the Aralo-Kaspiyskaya lowland. Moscow.

2. KOVDA, V. A. 1947. Present-day salt accumulation processes (halogenesis) in soils and water. Pochvovedeniye, No. 1.

3. KOSTYAKOV, A. N. 1947. Prevention of

water-logging and salinization of soils during irrigation. Nauchnyye zapiski Mosk. gidromeliorat. instituta Vol. XIII.

4. MALYGIN, V. S. 1913. Solonetzes, salinization of new areas influenced by artificial irrigation, and measures to control solonetzes. In the book: Trudy s'yezda khlopkovodov v Tashkente. (Transactions of the Convention of Cotton Growers in Tashkent). Doklady, Part II.

5. MALYGIN, V. S. 1939. Closed deep drainage. Tashkent. Soyuz NIKHI.

6. MAKRIDIN, P. V. 1934. Water-logging and salinization of lands on irrigated systems abroad, and engineering methods of controlling them. Bor'ba s zasol. pochv, Moscow.

7. MOROZOV, A. T. 1956. Applying calculations and analysis of the water-salt balance for reclaiming salinity regions. Trudy VIII ses. Akad. nauk Turkm. SSR.

8. RABOCHEV, I. S. 1955. Elements of the water balance of soils. Izv. Akad. nauk TSSR, No. 3.

9. RABOCHEV, I. S. 1953. Controlling ground water regime. In the book: Rezul'taty izuch. melior. zasolen. pochv v Turkmenistane, (Results of studying the reclamation of salinized soils in Turkmenistan). Ashkhabad.

10. RABOCHEV, I. S. 1960. Water balance of soil materials of the Chardzhouskiy oasis. Izv. Akad. Nauk TSSR. No. 3.

11. ROZANOV, A. N. 1956. Salinization and melioration of irrigated soils. Doklady VI Mezhdunar. kongr. pochvovedov. VI Komis. Melioratsiya pochv. izd. Akad. nauk SSSR.

12. ROZOV, L. P. 1936. Meliorative soil science. Sel'khozgiz.

13. FEDOROV, B. V. 1957. Causes of soil salinization and means of removing them. Khlopkovodstvo No. 12.

14. SHAUMYAN, V. A. 1948. Scientific principles of irrigation and irrigation construction. Sel'khozgiz.

HEAT OF WETTING AND CONTENT OF TIGHTLY BOUND WATER IN CLAY MATERIALS

N. P. ZATENATSKAYA, F. P. Savarenskiy Laboratory for Hydrogeological Problems, Academy of Sciences, USSR

Bound water and free water differ in clay materials by the character and magnitude of the forces of interaction between water and the solid phase. Bound water is divided into tightly bound water (adsorbed or hygroscopic) and loosely bound water (film, osmotic or water of diffused layers). Free water includes capillary and gravitational (immobilized) water. These forms of water differ in their properties; the so-called tightly bound water, the adsorbed or hygroscopic water of the first monomolecular layer at the boundary of separation between the surface of clay minerals - and water, has peculiar properties. The formation of a layer of tightly bound water is accompanied by an important powerful phenomenon - the formation of the heat of wetting; tightly bound water does not dissolve electrolytes, sugar and other substances, forming a "non-dissolving volume."

Detailed characteristics of the properties of tightly bound water are found in works of Andrianov (1), Rode (11), and others.

Several investigators (Dumanskiy (4), Rebinder (12), Ovcharenko (9), and others), assuming as the basis for separating water forms in clay materials the magnitude of the free energy of the bond, have related film water or the water of diffused layers to free water; other investigators (Dolgov (3), Rode (11), and Priklonskiy (10) have assigned it to loosely bound water, based on the rate of its mobility (movement) in the rock and other characteristics. The water in the finely dispersed clay materials is in a slightly mobile state. There is no sharp distinction between loosely bound water and free (capillary and immobilized) water.

In studying the geochemical equilibrium, "interstitial water as the adsorbing complex" of water-resistant clay materials which cover and underlie the middle upper Oligocene water-bearing horizon of the Tobol-Ishimskiy watershed, we will have to determine what portion of natural moisture constitutes tightly bound water, as the non-dissolving volume.

Given below are the results of determinations of tightly bound water in materials represented by continental lake - alluvial quaternary (Q_{1-2}) and Neogenic Aral clays (N_1^{1-2}), Chegan clays of the marine Paleogene ($P_{g_2-3}^{3-1}$) and clay silts of the middle Oligocene epoch ($P_{g_3}^{2}$). In mineralogical composition (from data of thermal, X-rays, and electron-microscopic studies) these clay materials are hydromicaceous (monothermite type hydromica) with an admixture of kaolinite.

The particle-size analysis of clay and clay silts is characterized by a < 0.001 mm diameter collodial fraction content of 30%-75%, and 6%-22%, respectively.

The adsorption capacity of the materials varies between 16 and 60 meg per 100 grams of material; among the adsorbed cations, magnesium and calcium ions are predominant over adsorbed sodium.

Table 1 gives the natural moisture characteristics of these materials from 17 samples (50 samples were analyzed), characteristics of moisture after squeezing out interstitial water under a pressure of 250 kg/cm² and the heat of wetting, content of tightly bound water, hygroscopic moisture, maximum hygroscopic moisture, and organic matter content.

Natural moisture in the materials depends upon several factors: the character of the materials, conditions of their occurrence, physical properties, content of organic matter, etc. The investigated clays in a state of complete water saturation ($Kw = 1$) contain 25%-40% natural moisture. Clay silts with a large content of organic matter (7%-12%) contain 45%-53% natural moisture. The moisture of the clays after squeezing out interstitial waters under a pressure of 250 kg/cm² decreased, on an average, by 20%-30% of natural moisture (Fig. 1).

We determined the amounts of tightly bound water by heat of wetting. There are presently many different means of determining quantitatively tightly bound-water - the method of non-dissolving volume (Trofimov [15], and Dumanskiy [5]), methods based on determining the heat of wetting, measuring electrical conductivity (Dolgov, [3]) and others. A widely applicable and most accurate method is that of determining tightly bound water by the heat of wetting (1).

The heat of wetting of the clay materials being studied was determined in #2 Andrianov

Table 1

Heat of wetting, tightly bound water, hygroscopic moisture, and maximum hygroscopic moisture of clay materials

Material, age	Hole No.	Depth of material selected, m	Content of fraction <0.001 mm, in diam., %	Heat of wetting Q, cal/g	Tightly bound water $W_{t.b.}$, %	Hygroscopic moisture of air-dried material, W_h, %	Maximum hygroscopic moisture $W_{m.h.}$, %	Ratio		Moisture		Organic matter content (after Tyurin) C_{org}, %	Ratio $\frac{W_n}{W_{t.b.}}$
								$\frac{Q}{W_h}$	$\frac{Q}{W_{m.h.}}$	Natural, W_n, %	After pressing with P= 250 Kg/cm², W_r		
Quaternary clay (Q_{1-2})	226	14,5	53,56	5,36	5,33	4,70	18,05	1,14	0,30	29,00	18,81	2,94	5,41
	492	4,5	61,99	6,29	6,26	6,90	18,76	0,91	0,34	32,40	27,00	0,44	5,15
Neogenic Aral clay (N_1^{1-2})	492	8,0	45,99	4,80	4,77	4,48	16,67	1,07	0,29	26,00	16,82	0,17	5,40
	223	9,0	46,62	6,84	6,81	6,37	15,44	1,07	0,44	26,71	17,43	0,25	3,90
	223	6,5	51,52	7,08	7,04	6,73	18,64	1,05	0,38	25.00	18,98	0,22	3,53
	302	8,5	58.44	6,63	6,59	6,14	16,35	1,08	0,41	25,40	20,82	0,15	3,83
	395	5,5	65,14	9,85	9,79	8,37	21,62	1,17	0,45	31,57	28,44	0,26	3,21
	228	5,5	65,90	7,00	6,95	6,45	19,10	1,08	0,36	30,28	27,20	0,05	4,32
	173	8,0	70,13	9,00	8,95	8,64	21,31	1,04	0,42	34,20	25,50	0,31	3,80
	223	4,0	70,20	13,10	13,06	9,76	27,00	1,34	0,49	39,86	29,10	0,37	3,04
	302	4,0	71,83	10,50	10,45	9.32	22,65	1,12	0,46	32,50	23,90	0,31	3,09
	228	3,5	74,82	11,29	11,24	9,80	24,62	1,15	0,46	36,36	30,83	0,10	3,22
Paleogenic Chegan clay, (Pg_{2-3}^{3-1})	304	62,0	20,70	3,50	3.48	2,73	8,90	1,28	0,40	27,25	14,84	1,16	7,78
	2	48,0	46,73	4,56	4,54	4,68	13,30	0,97	0,34	25,20	19,84	0,62	5,53
	9	16,0	57,68	4,79	4,76	3,94	16,07	1,21	0,30	28,76	21,54	1,73	6,0
Middle Oligocene clay silt, (Pg_3^2)	173	50,0	6,04	1,21	1,20	1,17	4,40	1,03	0,28	28,00	18,2	0,82	23,14
	173	32,0	22,33	5,51	5,47	5,04	14,21	1,09	0,38	52,7	36,5	11,86	9.56

Note; Comma represents decimal point.

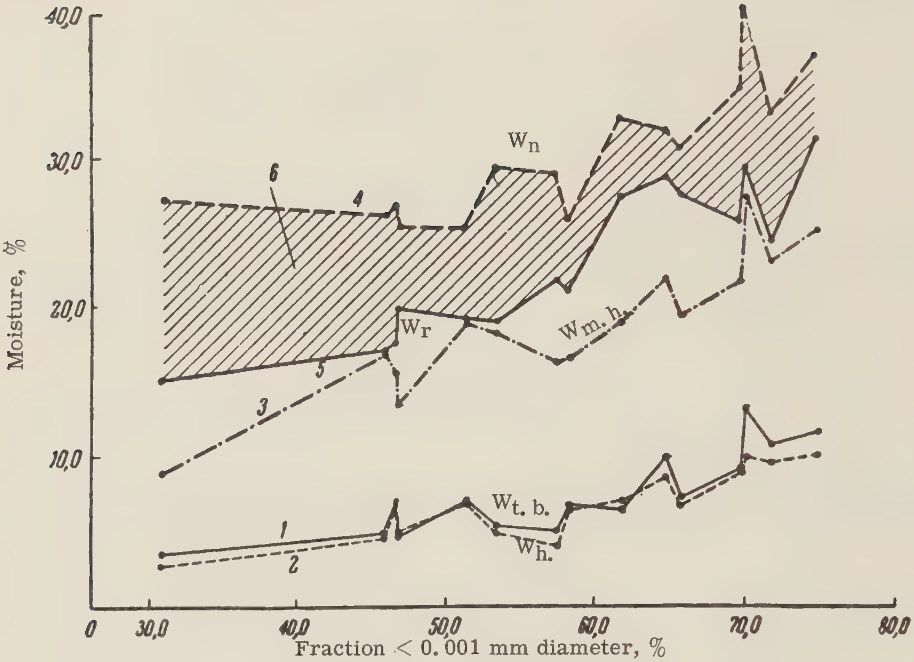


Fig. 1. - Forms of water in clay materials.

1 - $W_{t.b.}$ - Tightly Bound water; 2 - W_h - Hygroscopic moisture of air-dried rocks; 3 - $W_{m.h.}$ - Maximum Hygroscopic moisture; 4 - W_n - Natural moisture; 5 - W_r - moisture after squeezing out water when P = 250kg/cm^2 (Remainder); 6 - quantity of water squeezed out.

calorimeters with a temperature equal to 20° C; the material was prepared for analysis according to the methods of Sergeyev (14)[1].

The weight of the clay material sample had to be such that temperature rise in the calorimeter would correspond approximately to 1° C during determination of the heat of wetting. For coarse, finely dispersed clays the weighted sample was, on an average, 5-6 grams, for less dispersed clays the weight was increased to 8-10 grams. The material was dried to a constant weight in 6 to 8 hours. The amount of distilled water required for wetting was on an average, 1-1/2 to 2 times more than the weight of clay material. The dried clay and water were weighed with an accuracy to 0.001 g. The calorimeter read before wetting was +0.001° C, rarely +0.002° C. The Beckmann thermometer was read by using a magnifying glass with an accuracy to 0.002° C. To obtain reliable results, two parallel determinations were made; the discrepancies between determinations amounted to, on an average, 1%-3%.

The heat of wetting of clay materials depends upon their mineralogical composition, dispersion, and composition of exchangeable cations.

The relationship between heat of wetting and mineralogical composition has been studied in detail by several authors (13, 8, etc.). From Ovcharenko's (8) data, the heat of wetting of montmorillonite clay varies between 10 and 24 cal/g, and of monothermite clay between 5 and 6 cal/g; kaolinite clay and loess-like clay loam have a heat of wetting of 2.0-6.0 cal/g.

In structure the clay minerals are particles consisting of crystallized cells or packets constructed from layers of Al (OH)$_3$ alternating, in turn, with groups of SiO$_4$. The distances between surfaces of these packets are arranged along the axis C; for kaolinite they equal 2.76Å (or 2.76×10^{-8}cm), for montmorillonite from 9.5 to 20A.

The "rigidity" and constancy of the distances between packets in kaolinite are responsible for the limited interaction of kaolinite with water, whereas the packets of montmorillonite, easily extended along axis C, owing to the peculiarities in structure, create conditions for the vigorous bonding of a large quantity of water. The structure of the elementary cells in clay minerals is caused by their chemical composition and is characterized by a ratio of SiO$_2$ to Al$_3$O$_2$; the higher this ratio, the more water the clay binds.

The relationship of heat of wetting with dispersion of clay material has also been well-studied. An increase in dispersion of clay leads to an increase in the surface area of soil particles and to an increase in the quantity of bound water, and, consequently, of the heat of wetting formed. The fraction < 0.001 mm in diameter has the maximum heat of wetting.

---

[1] Heat of wetting was determined in the Soils Laboratory, Moscow State University (Russian text page 49).

The relationship of the heat of wetting with composition of exchangeable cation is seen by the fact that clays saturated by bivalent cations have a greater heat of wetting than do clays saturated by monovalent cations.

We see the most obvious relationship between heat of wetting and the degree of dispersion of clay (Table 1), in the poly-mineral clays under study (hydromica with a greater or lesser admixture of kaolinite).

The organic matter content in Quaternary and Neogenic Aral clays is small — ranging from 0.03%-0.9% (on an average, 0.3%) and only in individual samples does it amount to 1.1%-2.9%.

In the paleogenic marine Chegan clays the organic matter content is somewhat higher and, on an average, equals 1.2%. The greatest quantity of organic matter — 6.1%-11.8% - is found in the clay silts of the middle Oligocene. The role of organic matter in increasing the heat of wetting formed and in binding water is most clearly observed in clay silts where the heat of wetting increases to 5.5 cal/g when the content of the collodial fraction <0.001 mm in diameter is equal to 22% and the organic matter content about 12%. The heat of wetting of these clays with a 65%-75% content of particles < 0.001 mm in diameter is 7-13 cal/g; in clays with 30%-50% content of particles < 0.001 mm in diameter, the heat of wetting decreases to 3-5 cal/g (Table 1).

From the heat of wetting derived from an experiment, we can compute the content of tightly bound water by formula (6, 8):

$$A = \frac{Q \times h \times 100}{g} = \frac{Q \times 4.18 \times 10^{7} \times 2.76 \times 10^{-8} \times 100}{116} \qquad (1)$$

where A = amount of tightly bound water in %;
Q = amount of heat formed, cal/g;
h = thickness of the monomolecular layer of water, equal to 2.76×10^{-8} cm;
g = total surface energy of water and vapor ($g = 116$ erg/cm²); 4.18×10^{7} - multiple for converting the thermal unit cal/g into the absolute unit, erg.

Ovcharenko (9) determined the content of tightly bound water in clays by several methods: heat of wetting, hygroscopic moisture (55% relative air humidity) and the Dumanskiy indicator method. By comparing the amounts of tightly bound water obtained by these three methods (Table 2) we note a close similarity, which justifies the conversion of the heat of wetting by formula (1), based on the concept of the monomolecular layer of tightly bound water.

We observe in the clay materials being studied an obvious relationship between content of tightly bound water computed by the heat of wetting and the degree of clay dispersion (Fig. 2).

The hygroscopic moisture of these clays in an air-dried state (with a temperature equal to 18-20° C and a relative air humidity of about 50%) has the same numerical values as tightly bound water computed by the heat of wetting (Table 1, Fig. 1).

The ratio of the heat of wetting to hygroscopic moisture fluctuates between 0.91 and 1.34 and, on an average, equals 1.12. For soils, from Andrianov's data (1), this ratio is between 0.97 and 1.08; according to Dimo's data (2) the ratio is 1.20 (mean).

Dumanskiy and Dumanskaya (5), as well as Ovcharenko (9), point to the same similarity between the quantitative content of tightly bound water determined by two methods (heat of wetting and Dumanskiy's indicator method) and the hygroscopic moisture of air-dried clay materials (Table 2).

From the foregoing, we may conclude that these clay materials contain tightly bound water in an amount almost equal to the moisture of air-dried clays, and we may assume as the non-dissolving volume the water corresponding to the hygroscopic moisture volume.

To explain the relationship between the heat of wetting formed and tightly bound water

Table 2

Tightly bound water in clays and soils from data determined by various methods

Clay materials and soil	Amount of tightly bound water, %: by hygroscopic moisture	by heat of wetting	by indicator method	Investigators
Bentonite	19,0	20,9	22,1	Ovcharenko (8)
Krymskiy clay	21,0	19,6	21,3	
Gorbskiy beidellite	9,2	11,2	11,8	
Chasov-Yarskiy monothermite	6,3	5,4	7,0	
Kaolin	2,3	2,0	2,2	
Southern Chernozem	7,07	—	7,53	Dumanskiy and Dumanskaya (5)
Ordinary Chernozem	6,62	—	7,08	
Thick Chernozem	6,85	—	7,03	
Leached Chernozem	3,68	—	3,82	

Note: Comma represents decimal point

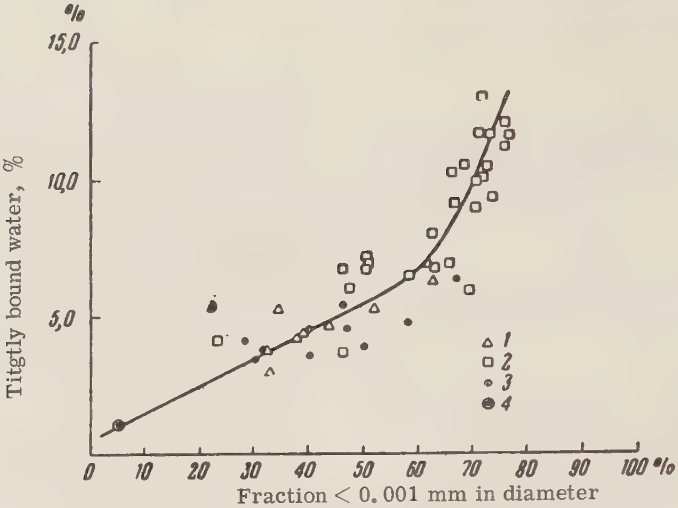


Fig. 2. - Relationship between the content of tightly bound water and the fraction < 0.001 mm in diameter.

1 - clay Q; 2 - clay N_1^{1-2}; 3 - clay Pg_{2-3}^{3-1}; 4 - silt Pg_3^{2-3}.

computed by it, on the one hand, and the maximum hygroscopic moisture in the clay materials, on the other, we determined maximum hygroscopic moisture of clays by the Nikolayev method (samples were placed in desiccators with a 98% relative air humidity over a saturated solution of K_2SO_4 with a temperature equal to 20° C for 2.5-3 months). The results of these studies are given in Table 1 and Figure 1. We see that the maximum hygroscopic moisture in these clays is almost three times more than the content of tightly bound water in the clays. The highest values (21%-27%) are observed in finely dispersed Aral clay, where the content of the fraction < 0.001 mm in diameter is 65%-75%.

The ratio of the heat of wetting to maximum hygroscopic moisture for these clay materials varies between 0.28 and 0.49 and, on an average, is equal to 0.38 (Table 1). The obtained data are evidence that the coefficient of proportionality established by Andrianov (1) between the heat of wetting and maximum hygroscopic moisture, equal to 0.517, is not a constant value. Dimo (2) arrived at the same conclusion in her work; for the soils which she studied the ratio in question varied between 0.37 and 0.68.

A. V. Dumanskiy and F. D. Ovcharenko (6, 8) studied the heat of wetting of clay materials as a function of their moisture. To achieve a varying moisture, weighed samples were kept for several months in desiccators with a sulfuric acid of specific concentration (5-10-15-25-50-70-90%); then the moisture and heat of wetting of these samples were determined. Experiments showed that the total wetting of the clay material (heat effect approaching zero) occurs when the vapor pressure is 15-16 mm of mercury column, which approximately corresponds to a H_2SO_4 concentration of about 20%. The maximum hygroscopic moisture in the clay materials was determined usually when the vapor pressure was higher than 15-16 mm of mercury column (the Mitcherlikh method of 10% H_2SO_4 or the Nikolayev method of a saturated solution of K_2SO_4) and, consequently, there occurs in conjunction with vapor adsorption a capillary vapor condensation in the pores of the clay.

It follows from this that an identification of the amount of tightly bound water with moisture corresponding to maximum hygroscopic moisture, as is occasionally assumed, has no basis.

The presence in the clay materials of hygroscopic salts increases the values of maximum hygroscopic moisture. To show the effect of chlorides (the salts NaCl and $MgCl_2$ are present in the pore solution centrifuged from the clay material) on the value of maximum hygroscopic moisture, we determined the maximum hygroscopic moisture of salinized samples and of samples leached of chlorides. As we see from Table 3, the maximum hygroscopic moisture of clays leached of chlorides is 10%-20% less than that of salinized samples.

To derive a sufficient volume (5-10ml) of pore solution for geochemical studies, interstitial waters were squeezed out from the clay materials in special apparatus (press-forms) designed by Kryukov (7) under a pressure of 250kg/cm² created by a 4-ton hydraulic press. The clay material pressed until the separation of the pore solution under a given load ceased. In addition it was discovered that the pressing time for clays of varied dispersion was not the same. For highly dispersed Aral clays it took 7-10 days whereas for less dispersed Chegan clays and quaternary clay loams we derived the same amount of interstitial water in 10-14 hours.

Table 3

Effect of chlorides, found in a pore solution of clay, on the magnitude of maximum hygroscopic moisture

Clay material, age	Hole No.	Depth of clay material selected, m	Content of particles <0. 001 mm in diam., %	Maximum hygroscopic moisture, $W_{m.h.}$ %		Decrease in $W_{m.h.}$ in %, after leaching of chlorides	Clay salinization by soluble salts in % per 100g of dry clay
				Before leaching of chlorides	After leaching of chlorides		
Quaternary clay (Q_{1-2})	481 492 492 226	2,5 4,5 6,5 14,5	32,75 61,99 15,70 53,56	8,60 18,76 4,54 18,05	7,30 16,72 3,78 14,49	15,0 11,0 17,0 20,0	0,06 0,69 0,33 0,82
Neogenic Aral clay (N_1^{1-2})	489 489 492 223	4,5 6,5 8,0 9,0	71,75 22,99 45,99 46,62	20,00 10,92 16,67 15,44	18,90 7,09 15,42 13,54	5,0 35,0 7,0 12,0	0,45 0,33 0,14 0,32
Paleogenic Chegan clay (Pg_{2-3}^{3-1})	9 2 304	16,0 48,0 62,0	57,63 46,73 30,70	16,07 13,30 8,90	14,30 12,10 7,70	11,0 9,0 13,0	0,03 0,03 0,20

Note: Comma represents decimal point

Table 4 gives the typical moisture and porosity values for clays of varied genetic types. The natural moisture of finely dispersed Aral clay is greater (38.7%) than that of less dispersed Chegan clay (29%), but the absolute amount of total free and loosely bound water i.e., water equal to natural moisture minus tightly bound water for both one or another type of clay, is approximately the same and equals 25%-27%. Both clay materials are in a state of complete water saturation. The porosity of Aral clay is 51%, of Chegan clay 42.4%. The different rates of squeezing out interstitial water imply a varied mobility or movement of free water in these clays depending upon the degree of their dispersion and the content of adsorbed tightly bound water, in other words, upon the hydrophilic nature of these clays. The size and shape of the pores, as we know, is closely related to the degree of clay dispersion (the higher the dispersion, the smaller the pore diameter) while the available (water-conducting) part of the pores depends also upon the quantity of adsorbed water. The content of tightly bound water in the finely dispersed Aral clay is almost 2-1/2 times greater than that in Chegan clay (11.60%, as against 3.90% of gravimetric moisture); the tightly bound water in Aral clay is 30% of the total pore volume, while in Chegan clay it is only 14%; the ratio of W_n to $W_{t.b.}$, on the contrary, is greater for less dispersed Chegan clay and equals 7.16 as opposed to 3.34 for Aral clay (Table 4, Fig. 3). Based on this, we may

Table 4

Porosity and water content in clays

Clay material and age	Depth of rock selected m	Content of fraction <0.001 mm in diameter, %	Natural moisture W_n, %		Porosity n, %	Coefficient of water saturation KW	Tightly bound water, $W_{t.b.}$ %		$\frac{W_n}{W_{t.b.}}$	Moisture after squeezing out water when p=250kg/cm² W_r, %
			Gravimetric	Volumetric			Gravimetric	Volumetric		
Neogenic Aral clay (N_1^{1-2})	7,0	76,12	38,70	51,0	51,0	1,0	11,60	15,30	3,34	30,80
Paleogenic Chegan clay (Pg_{2-3}^{3-1})	95,0	34,29	29,00	42,4	43,0	0,98	3,90	6,00	7,16	21,20

Note: Comma represents decimal point

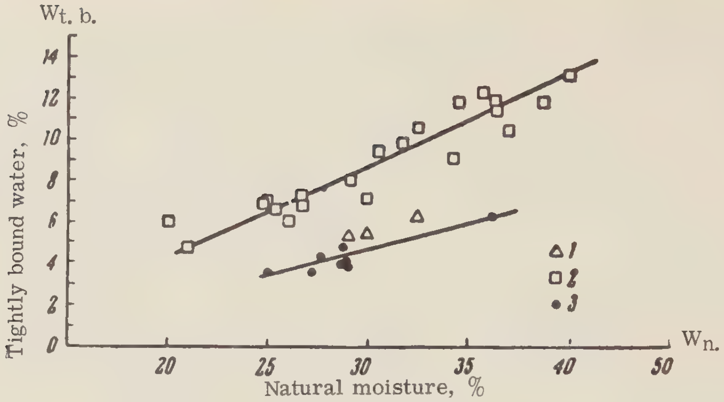


Fig. 3. - Ratio of natural moisture to content of tightly bound water in water-saturated clays (Kw = 1).

1 - clay Q; 2 - clay N_1^{1-2}; 3 - clay Pg_{2-3}^{3-1}.

assume that the water contained in the finest capillaries of Aral clay is considerably less mobile and so makes squeezing more difficult and slower under a load of 250 kg/cm_2 as compared with the water contained in the coarser pores of Chegan clay.

Conclusions

1. Investigations of tightly bound water by heat of wetting have shown that the clay materials under study contain tightly bound water in an amount approaching hygroscopic moisture.

2. We can assume as the non-dissolving volume the volume of water corresponding to the hygroscopic moisture of the air-dried clay.

3. The moisture corresponding to maximum hygroscopic moisture, according to experimental research data, is almost 3 times greater than the content of tightly bound water in the clay material and it would be incorrect to identify it with tightly bound water.

4. When we apply pressures of 250 kg/cm_2 for squeezing interstitial waters, free water is not entirely centrifuged; a longer period of time is required to squeeze out interstitial waters when the hydrophilic character of clay materials increases.

Received May 22, 1960

BIBLIOGRAPHY

1. ANDRIANOV, P. I. 1937. Heat of wetting and unit surface of soils. Fiziko-agronomicheskiy institut, izd. VASKHNIL.

2. Dimo, V. N. 1946. Problem of the heat of wetting of soils, minerals, and rocks and its relationship to surface properties. Pochvovedeniye, No. 5.

3. DOLGOV, S. I. 1948. Studies of soil moisture movement and its availability to plants. Izd. Akad. Nauk SSSR, Moscow and Leningrad.

4. DUMANSKIY, A. V. 1934. Water in colloidal systems. Izv. gos. nauchno-issledovatel'skogo instituta kol. khimii. vyp. 2, Voronezh.

5. DUMANSKIY, A. V., and A. P. DUMANSKAYA, 1934. Bound water in soils. Izv. gos. nauchno-issledovatel'skogo instituta kol. khimii. vyp, 2 Voronezh.

6. DUMANSKIY, A. V., and F. D. OVCHARENKO. 1950. Heat of wetting of Glukhovskiy kaolin and Chasov-Yarskaya clay. Kolloidnyy zhurnal. No. 5.

7. KRYUKOV, P. A., and N. A. KOMAROVA. 1956. Study of soil, clay, and parent material solutions. In the book: Doklady VI. Mezhdunarodnogo kongressa pochvov. (Reports of the Sixth International Congress of Soil Scientists). Komis. 2, Izd Akad Nauk, SSSR.

8. OVCHARENKO, F. D. 1955. Hydrophilic character of clay. Thesis for Doctor's degree (?) im. Lenina. Moscow.

9. OVCHARENKO, F. D. 1958. Hydrophilic character of clay. Materialy po geol., mineral., i ispol'zov. glin v SSSR. Izd. Akad Nauk, SSSR.

10. PRIKLONSKIY, V. A. 1955. Soil Science, Part I. Gosgeoltekhizdat.

11. RODE, A. A. 1952. Soil moisture. Izd. Akad. Nauk, SSSR.

12. SERB-SERBINA, N. N., and P. A. REBINDER. 1958. Physicochemical principles of controlling the structures and mechanical properties of clays and clay

materials. Materialy po geol., mineral., i ispol'zov. glin v SSSR. Izd. Akad. Nauk, SSSR.

13. SERGEYEV, YE. M. 1947. Problem of correlating certain soil properties. Vestnik Moskovskogo gosudarstvennogo universiteta, No. 2.

14. SERGEYEV, YE. M. 1951. Methods of determining the heat of wetting of soils. Uchennyye zapiski MGU, Gruntovedeniye, vyp. 149 book 2.

15. TROFIMOV, A. V. 1925. Recognizing the separated part of the soil solution. NAZH No. 10.

DATA ON THE DYNAMICS OF SOIL-FORMATION PROCESSES IN SOLODIZED SOILS OF THE ALTAYSKIY KRAY

T. V. TURSINA, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

In the Altayskiy Kray and adjoining areas the phenomenom of soil solodization is widespread and varied (1, 3, 4, 5, 8). Solodized soils in the Altayskiy Kray are found in subzones of ordinary and southern Chernozems and in the dark-chestnut soil zone. Among the zonal soils the solodized soils occupy up to 10%-15% of the area. They are associated with specific types of relief and microrelief and are distributed in various kinds of hollows and depressions. The particularly numerous depressional forms of relief are associated with terraces of ancient drainage basins as well as with young, and with river terraces.

Solodized soils are represented both by soils with a well-formed solodized horizon, properly speaking, solods beneath birch and birch-aspen forests, and by soils with an undefined or an insufficiently clearly formed solodized horizon (as, for example, solodized solonetzes and meadow-bog solodized soils) or with some other, concealed, soil-formation process (transitional soils from solods to gray forest and meadow chernozem soils).

Solods are always associated with solonetzes, meadow chernozem solonetz-like or meadow-bog soils, sometimes with solonchaks forming typical meadow or meadow-steppe combinations and complexes, which are easily and quickly detected by using aerial methods (13, 15). The components of the latter soils change, depending upon the age and, consequently, upon the extent of drainage in the area. Meadow-bog solonchak-like solodized soils are formed on young terraces (Fig. 1) in waterlogged depressions beneath sedge-reed vegetation; solonetzes-solonchaks are formed along the periphery of these depressions beneath extremely sparse halophytic vegetation; on the upper part of the slope beneath wild rye-wormwood-mulberry tree associations are found crusty-solodized solonetzes; peat-gley solods are found in the depressions among these solonetzes beneath willow-birch-aspen plantings.

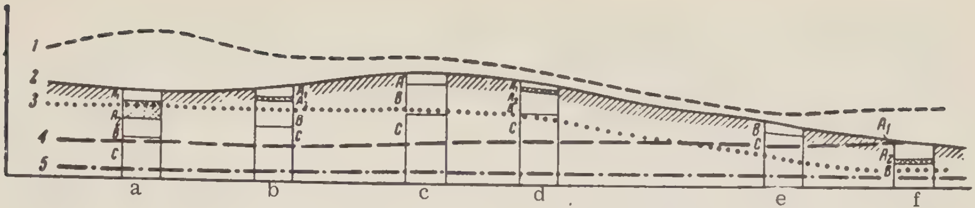
On higher terraces we observe a decrease in salinization and meadow development of soils. Meadow-bog solodized soils are developed in the depressions; on slopes leading to the depressions are found crusty solodized solonetzes; meadow solods are found in the depressions beneath birch-aspen stands. Chernozem-meadow solodized soils appear on the more ancient and better-drained terraces in the depressions of the relief; deep solonetzes are found on the slopes, while in the birch stand depressions we find soils which are in transition from solods to gray forest soils. Finally, we encounter at the interfluves, in the depression forms of relief, meadow-chernozem soils; on slopes the solonetz-like chernozems; and in the birch-stand depressions, gray and dark-gray forest soils. The components of the complexes and combinations have a definite genetic relationship among one another.

Most prevalent is the concept of solod formation under the influence of a downward flow of atmospheric precipitation by means of the composition of the adsorption complex of desalinized solonetz with a subsequent entry of hydrogen in place of adsorbed sodium. Gedroyts (2) considers that "only solonetz soils are subject to the solodization process." Ivanova (5) confirms and develops this point of view: "Solods and solodized soils originate from solonchaks by way of solonetzes."

Studies by Rybakov (12) on the ancient Lesnoy-Voronezh River flood-plain show that solods may be formed without the development of the solonetz stage, that is, directly during the solodization of the bog or semi-bog soils. "In such cases of solodization the adsorbed Na, obviously, is added into the adsorption complex from diluted solutions of ground waters, at a time when the capillary rise prevails over the downward flow."

We find a similar explanation of the solodization process in the works of Basilevich (1): "with the slow process of dissection of relief and a relatively high standing of ground waters associated with this process, a regime of periodically recurrent soil treatment by weakly mineralized sodium carbonate solutions is established for a long period of time. In this case the development of a salinized soil complex proceeds in the direction of 'solodization'."

In Popov's opinion (11) solod formation is sometimes possible from solonetzes via meadow-bog soils. The soil may subside on solonetzes when the surface-melted snows stand too long and when small depressions which are gradually overgrown with bog vegetation are formed. With a general drying-up of the area, willow followed by aspen and birch penetrate



Scale: vertical, 1 cm = 1 m
horizontal, 1 cm = 20 m

Fig. 1. - A levelled profile of a solonetz-solodized complex.
a - meadow solod; b - gray forest solodized soil; c - deep solonetz; d - crusty solodized solonetz; e - solonetz-solonchak; f - meadow-bog solodized soil; 1 - height of snow cover in March, 1957; 2 - soil surface; 3 - freezing depth in March, 1957; 4 - ground-water level in May, 1956; 5 - ground-water level in September, 1956.

these bogs while the soil is being transformed into solod.

A more precise description of the means by which solods are formed was not included in the program of our studies. We were assigned the task only of showing, by specific example, what present-day soil-formation processes are taking place in the solodized soils of the Chernozem zone of the Altayskiy Kray. To make a detailed study, we selected the solonetz-solodized complex consisting of meadow-bog solodized soil, crusty-solodized solonetz, and meadow solod beneath a birch-aspen stand. The purpose of our research was to ascertain whether similar soil-formation processes were presently taking place in these solodized soils. Until recently there has been no research on the contemporary soil-formation processes on solodized soils. It has been only in the last few years that the Soil Science Department of the Timiryazev Agricultural Academy (TSKHA) headed by Yarkov and Kaurichev (16, 17, 18) has initiated extensive research on the study of the dynamics of the soil-formation processes in various zones of the Soviet Union, including soil-formation processes on solodized soils.

Solodized soils, as soils of a hydromorphous subtype, are developed under the direct influence of high soil-ground waters, which occur beneath these solodized soils at a depth no greater than 3 m, depending upon the overall drainage of the area (Table 1). The ground-water level over a 3-year observation period dropped 1-1.5 m between spring and fall (less on the lesser drained strips).

Table 1

Change in ground-water level, cm

Sampling time	Profile No. 338 meadow solod	Profile No. 349 Meadow-bog solodized soil	Profile No. 337 Crusty solodized solonetz
Sept. 1955	255	Not det'd.	270
June 1956	130	Inundated from the surface	140
July	200	70	210
Sept.	240	105	260
June 1957	130	50	130
July	180	90	180
Aug.	220	100	230

As the data in Table 2 shows, the ground waters beneath solodized soils are mineralized from 0.2-0.4 (beneath solods) to 2.0 g/liter and more (beneath meadow-bog solodized soils) and beneath solonetzes 0.7-0.84 g/liter. In 1956, marked by a wet summer, there occurred towards fall a decrease in water mineralization beneath solodized solonetz and meadow-bog solodized soil; in the dry year of 1957 ground-water mineralization increased towards fall beneath these soils. Changes in mineralization beneath a solod are extremely negligible and specific between spring and fall. In May and June mineralization was the highest, chiefly as a result of an increase in the content of water-soluble humus; in July it decreased because of the replenishment of water by fresh-melted snows, while in August and September mineralization again increased from ground-water evaporation and root absorption.

In salt composition the ground waters beneath all solodized soils have characteristics in common: sodium carbonates and bicarbonates are predominant. However, the quantitative content of these soils in the waters differs. In addition, the accompanying salts are also different: beneath the solod, besides sodium carbonates and bicarbonates, there exist small quantities of calcium and magnesium carbonates and bicarbonates, with an admixture of sulfates; beneath the solodized solonetz are magnesium and carbonate bicarbonates (very little calcium bicarbonate) as well as a small quantity of sulfates; beneath meadow-bog solodized soil are sulfates, to a lesser extent, sodium chlorides and, partly, magnesium chlorides.

Thus, these soils, by occupying different positions in the micro and meso-relief, have a single-type sodium carbonate ground-water salinization, which, definitely, is the reason

Table 2

Change in ground-water mineralization beneath solodized soils, in meq/liter

Profile No.	Soil	Time of sample	Solid residue g/liter	Alkalinity		Cl	SO_4	Ca	Mg	Spectral Na	Spectral K	Water soluble humus, meq/liter
				CO_3	HCO_3							
338	Meadow solod	Apr. 1955	Not det'd.		6,96	0,22	None	2,80	None	4,38	Not det'd.	
		May 1956	0,400	0,82	6,60	None	0,58	1,04	0,69	5,48	0,04	Not det'd
		July	0,280	0,52	5,25	"	0,48	2,11	0,75	2,65	0,03	"
		Sept.	0,334	0,45	5,03	"	0,29	1,32	0,55	3,78	0,02	"
		May 1957[a]	0,205	None	1,60	"	0,36	1,45	0,60	None	None	0,05
		June	0,338	"	4,77	"	None	3,04	0,80	1,39	0,05	Not det'd
		July	0,310	0,38	3,75	"	"	2,24	0,89	0,65	0,02	"
349	Meadow bog solodized	July 1956	1,946	1,88	15,58	1,29	13,91	0,70	1,04	28,70	0,04	Not det'd
		Sept.	1,060	1,35	12,16	0,77	5,65	0,97	1,24	18,04	0,07	"
		June 1957[a]	1,006	1,28	12,12	0,33	3,64	1,18	2,76	11,53	0,23	0,07
		June	0,924	2,18	26,16	0,82	15,84	0,45	7,40	37,06	0,05	0,05
		Aug.[a]	1,772	2,77	21,39	0,74	2,72	2,99	3,36	18,49	0,46	0,09
		Aug.	2,208	2,25	20,64	1,65	12,36	0,98	6,87	28,93	0,09	0,03
337	Solodized solonetz	Sept. 1955	Not det'd.		13,04	0,34	0,48	0,00	2,38	10,58	Not det'd.	
		May 1956	0,698	2,25	13,74	None	0,29	0,29	1,26	12,40	0,05	Not det'd
		July	0,642	1,13	11,56	"	0,09	0,52	2,91	8,26	0,03	"
		Sept.	0,628	1,27	10,92	"	0,29	0,28	2,28	8,69	None	"
		May 1957	0,740	2,85	11,19	"	None	0,45	1,96	10,66	0,05	"
		Aug.	0,810	1,88	12,20	"	"	0,69	2,00	11,05	0,04	"

---

[a] Surface melted snow.

Note: Comma represents decimal point.

for the development of solonetzization and solodization in these waters.

In the spring, prior to the beginning or middle of June, the solods of birch stands are flooded by melted snows. The surface waters at the center of the stand, concentrated at the beginning of June 1957, had a 0.20 g/liter mineralization and in composition belonged to the calcium bicarbonate group, with a content of water-soluble humus as much as 50 mg/liter; Na in these waters was practically nil. It is probable that the fresh surface waters are formed almost exclusively from the melting of snow, which has been accumulated during the winter in the stand itself.

The woody vegetation of stand depressions contributes to the accumulation within the stand and at their edges of a thick snow cover (to 2-2.5 m). On the cane bogs we also observe a thicker snow cover (1-1.5 m), as compared with the surrounding area. The average snow cover on open areas is 25-35 cm; in places, it is entirely missing. Minimum thickness occurs in birch stands and on reed bogs (0.20-0.24); the greatest thickness is on the exposed areas (0.33-0.35).

Observations of the freezing depth of solodized soils in February and March, 1957 showed that depth is directly related to the thickness of the snow cover; solods froze least of all at a depth of 70-80 cm, while least freezing of solonetzes took place at 1-1.2 m. These indicators are somewhat below the mean soil-freezing data of soils of the Altayskiy Kray (11). It is probable that the surface horizons, which have been subject to excess moisture since fall, have preserved the soil from a deep freeze in 1957.

Observations show that the moisture regime of solodized soils is heterogeneous (Fig. 2). We can distinguish 3 parts in the moisture profile of all soils studied: an upper part with a wide range of moisture; a center part with a relatively stable moistening and negligible fluctuations in moisture; and, a lower part, the zone of fixed or constant wetting as a result of capillary saturation from ground waters. However, the moisture content in each soil and its change in the course of a year is strictly defined.

The maximum moisture content in solods is

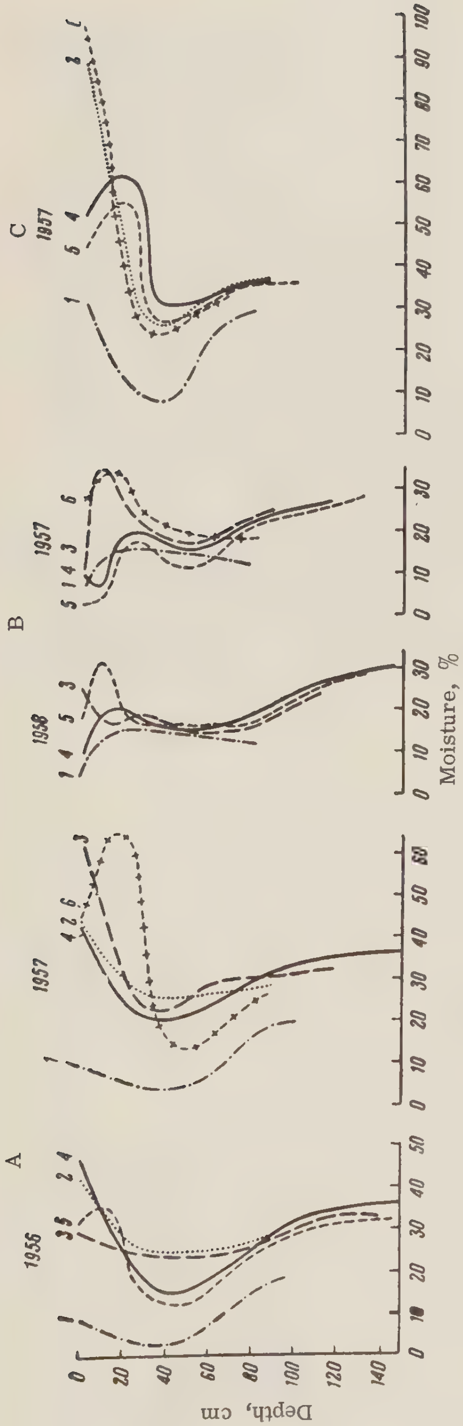


Fig. 2. - Change in moisture, as a percentage of the volume.

A - Profile No. 338, meadow solod; B - Profile No. 337, solodized solonetz; C - Profile No. 349, meadow bog solodized soil; 1 - maximum hygroscopic moisture; 2 - minimum (field) moisture capacity. Moisture; 3 - in May; 4 - in July; 5 - in September; 6 - in March.

observed in the A_1 horizon (50%-60% of volume) and takes place at the end of winter and in the spring, this horizon dries to 27%-25% in the summer. In the center part of the profile, moisture fluctuations, between 25% in the spring and 12%-13% in the fall, are possible in the A_2 and A_2/B_1 horizons. In the winter we also note a low moisture (12%-14%) in these horizons. In the B_1, B_2, and C horizons the moisture remains practically constant during the course of an entire year (31%-33%), and corresponds to the minimum field moisture capacity. Thus, throughout the entire solod profile up to the horizon of capillary-moisture capacity, the spring moisture is above the minimum field-moisture capacity (MFM), and after July decreases below minimum field moisture capacity. The A_2 and B_2/B_1 horizons dry up in winter, and moisture increases in the A_1 horizon because of moisture migration; that is, we can observe at the boundary of the A_2/B_1 horizons a break in the capillary continuity. In the spring, as a result of ground-water replenishment, we observe the joining of surface waters to the capillary fringe. At the end of May and the A_1 horizon begins to dry up, followed in July by the A_2 horizon and the upper part of the B_1 horizon. As the drying continues, the movement of capillary or film-capillary moisture towards the transitional A_2/B_1 horizons takes place. Under snow the solod is excessively wet in the upper part of the profile.

Thus, the downward flow of moisture is predominant in the solods in the spring and partly in the fall, as a result of infiltrated atmospheric precipitation. However, in the summer and winter the upward flows predominate because of high ground waters. Consequently, in the solods, leaching of the soil profile by fresh waters alternates with the attraction into the transitional horizon — from the solodized to the illuvial horizon (A_2/B_1) — of capillary solutions rising from weakly mineralized sodium and carbonate ground waters.

In the meadow-bog solodized soil the moisture of the surface-peat horizon varies widely in the course of a year — between 100% at the end of winter and spring and 40% at the end of summer; lower throughout the profile, in the mineral horizons, the fluctuations are less significant; in the A_1/A_2 horizons at a depth of 30-38 cm, the moisture during a season varies between 30% in the spring and 20% at the end of summer. In the capillary-fringe zone in the A_2 and B_1 horizons, the moisture is constant; about 35%-37%. In the meadow-solodized soils the downward flow of moisture predominates in the spring; in the summer we observe a temporary upward flow into the actual surface horizons; the formation of a temporary upward flow of moisture from the lower lying horizons is likewise possible during winter, in connection with the drying up of the A_1/A_2 and the A_2 horizons below the minimum field-moisture capacity.

In the solodized solonetz at the upper part of the profile (in the A_1, A_2, and B_1 horizons) the moisture fluctuations are considerable — ranging from 20%-25% in the spring to 1.5%-3% in the fall. In the illuvial B_2 and B_3 horizons, the moisture during the course of an entire year remains constant and very low, close to maximum hygroscopic moisture (MHM).[1] In the spring the A_1, A_2 horizons, and the upper part of the B_1 horizon have an excessive amount of moisture, but only for a short time. The moisture in the upper horizons evaporates rapidly, and in July the moisture in the A_1 and A_2 horizons drops below the MHM. But during dry years, as, for example, 1957, the moisture was, by September, below MHM practically throughout the entire profile. Movements of moisture from the capillary fringe into the dried up "dead layer" were not observed.

Thus, the solodized soils under study do not have the same moisture conditions. The meadow-bog solodized soil is excessively moist for almost the entire year; temporary upward flows of moisture are possible in this soil only in the fall. The solod is characterized by periods of excess or optimal moisture alternating with periods of drying. Consequently, downward flows of moisture alternate with upward flows. Solodized solonetz occurs under the peculiar conditions of spring, surface, temporary, excess moisture, and alternating with summer and fall drying of the capillary suspended moisture. The center of the profile – the illuvial solonetz horizons – is in a state of constant drying.

The oxidation-reduction-regime of solodized soils depends upon moisture conditions (6, 7, and 10). Measurement of the oxidation-reduction potential (ORP) of solod in May, during the standing of melted snows in a depression, produces reduced values (150-200-400-mv) in the A_1 and A_2 horizons. (Table 3). Immediately after the melted snow has descended throughout the entire solod profile, a high potential of 600-500 mv is established. In August the oxidation-reduction potential in the A_2 horizon dropped from 620 mv to 510 mv. This ORP drop can be explained by the loss (in connection with the drying of the A_2 horizon) of organo-iron complexes, which have migrated with the solutions into the illuvial-soil horizons. In 1957 the values of the ORP at the start of summer, which was marked by cool and rainy weather, were lower than in 1956. In August we again observed a drop in ORP in the A_2 horizon. In all, by ORP values the solods approach podzolic soils, for which Serdobol'skiy (14) cites ORP values of 600-700 mv.

In the meadow-bog-solodized soil during the first half of the summer the ORP in the surface-peat horizon dropped sharply amounting to 175 mv in 1956, and even minus 90 mv in the more moist year of 1957. At the end of July the ORP in the surface horizon and throughout the entire profile increased to 550-570 mv,

Table 3

Change in the Oxidation-Reduction Potential, mv

Profile No. and Soil	Horizon and depth, cm	1956			1957			
		June	July	Aug.	May	June	July	Aug.
338. Meadow solod	A_1 0—10	+610	+610	+625	+160	+505	+540	610
	A_1/A_2 18—26	+620	+650	+620	+200	+520	+560	620
	A_2 26—36	+610	+620	+510	+400	+590	+610	
	40—50	+610	+620	+510	Not det'd.	+610	+630	560
	B_1 70—80	+610	+620	+610	″	+570	+580	570
	B_2 90—95	+580			Not det'd.			
	C 100—120	+595	+570	+580	″			
349. Meadow bog solodized	A_T 8—10	Not det'd.	+175	+560	Not det'd.	— 90	+450	Not det'd.
	A_1 31—32	″	+400	+550	″	+150	+470	″
	A_2 40—43	″	+510	+520	″	+480	+460	″
	B_1 50—52	″	+490	+570	″	Not det'd.	+460	″
	B_2 70—80	″	+490	+565	″	″	+520	″
337. Solodized solonetz	A_1 0—3	+530	+530	+450	Not det'd.	+440	+500	Not det'd.
	A_2 7—8	+470	+465	+490	″	Not det'd.		″
	B_1 14—15	+470	+465	+490	″	+420	+440	″
	B_2 24—26	+480	+460	+470	″	+450	+420	″
	B_3 40—41	+470	+460	+475	″	+440	+420	″
	70—72	+475	+480	+510	″	+470	+420	″
	C 100	+485	+490	+490	″	Not det'd.		″

---

[1] It was impossible to determine the minimum field moisture capacity in solodized solonetz because of the high swelling of the upper part of the B_1 horizon and its total water impermeability. Since the A_1 and A_2 horizons under these conditions were super-saturated with water, we likewise failed to determine a sufficiently reliable value for minimum field-moisture capacity.

Table 4

Change in the pH value $(\frac{\text{salt}}{\text{water}})$

Profile No. and soil	Horizons and depth, cm	1956			1957		
		May	June	Sept.	May	July	Aug.
338. Meadow solod	A_1 3—10	4,94/5,36	4,74/5,48	4,58/5,68	4,72/5,84	5,26/6,28	—
	A_1A_2 10—18	4,82/5,66	4,88/5,46	4,32/5,82	3,58/6,04	4,98/5,92	—
	A_2 33—40	4,56/5,79	4,52/5,82	4,48/6,17	3,72/5,96	4,60/5,84	—
	45—55	4,50/6,22	4,46/5,88	4,20/6,08	3,58/5,76	4,62/5,96	—
	A_2B 55—67	4,56/6,26	4.42/6,54	4,07/6,28	—	—	—
	B_1 70—80	5,76/7,56	4,28/6,58	5,04/7,20	4,55/6,32	6,22/7,06	—
	B_2 110—120	6,54/8,27	6,38/8,30	5,80/7,92	6,14/7,56	6,30/8,07	--
	C 150—160	—	7,18/8,66	6,12/8,00	—	—	—
	200—210	—	7,44/8,46	7,55/8,74	—	—	—
349. Meadow bog solodized	A_T 0—12	—	6,44/7,44	6,00/6,88	—	8,06/9,28	8,20/9,06
	A_1 15—25	—	6,90/8,24	6,60/8,12	—	7,90/9,52	7,84/9,28
	A_1/A_2 30—38	—	7,92/9,32	7,50/8,30	—	—	—
	A_2 38—40	—	8,16/9.37	7,86/9,14	—	8,50/10,20	8,26/10,08
	B_1 50—60	—	7,54/9,20	7,26/8,54	—	—	—
	B_2 70—80	—	7,54/9,20	7,34/8,96	—	—	—
	C 100—110	—	--	7,88/8,66	—	—	—
337. Solodized solonetz	A_1 0—4	6,38/7,00	6,36/7,56	6,36/7,65	7,32/8,74	7,30/8,70	—
	A_2 5—8	8,20/9,74	7,52/8,53	7,70/9,63			
	B_1 10—20	8,64/9,94	8,54/10,05	8,66/10,15	9,24/10,66	9,20/10,67	—
	B_2 22—30	8,76/9,96	8,76/10,06	8,88/10,08	9,32/10,76	9,35/10,80	—
	B_3 40—50	8,68/9,98	8,76/10,10	8,76/10,05	9,44/10,80	9,50/10,95	—
	C 70—80	—	8,36/9,94	8,42/9,96	9,16/10,58	9,08/10,52	—
	110—120	—	8,16/9,67	8,10/9,81	—	—	—
	130—140	7,86/9,37	7,92/9,56	7,94/9,57	—	—	—
	200—210	—	7,74/9,10	7,68/9,00	—	—	—

Note: Comma represents decimal point.

maintaining these values until fall. At the same time we detected a 40-50 mv drop in the ORP in the horizon of greatest drying, the A_2.

The oxidizing-reducing potential in the solodized solonetz is sufficiently constant, throughout the profile, fluctuating during the spring, summer, and fall between 470 and 530 mv with a maximum in the A_1 horizon. Certain variations, depending upon a greater or lesser drying of the soil and the activity of the micropopulation, are observed only in the actual surface horizon.

Thus, solodized soils differ in the oxidation-reduction potential. We do not observe in solonetz any substantial changes in ORP throughout the profile during the spring, summer, and fall months and the ORP values are sufficiently high. Extremely short term conditions of surface anaerobiosis exist in solods during the spring. After the melted snows have descended, high ORP values are established without any particular profile differentiation by ORP. Only during the driest late-summer months do we observe in the solodized horizon a decrease in the oxidation-reduction potential. In the meadow-bog solodized soil the period of anaerobiosis is considerably longer. Aerobic conditions are established in the midst of the summer while at the end of summer in the solodized horizon, as in the solod, a decrease in the oxidation-reduction potential is noted.

Observations for changes in the pH of solodized soils during the spring, summer, and fall have shown that these changes in each soil can be considerable and extremely variable (Table 4). The solods have an acid reaction in the upper part of the soil profile over an entire season, and a weakly alkali reaction in the capillary fringe zone. We see a great difference between the salt and water pH values in the upper part of the soil profile of a solod, which points to great exchangeable acidity. Exchangeable H and Al (Table 5) have been detected to a depth of 70 cm. The greatest exchangeable acidity and the highest content of exchangeable H and Al are typical of the A_1, A_1/A_2, and the A_2 horizons.

The acid reaction of the upper part of the soil profile is explained by the accumulation of acid decomposition products of organic residue. In 1957, following an extensive flooding of the birch-stand depressions by melted snows, acidification became more strongly developed, especially in the A_2 horizon. This is also explained, apparently, by the formation of available complex acid organo-iron compounds under anaerobiosis conditions (Table 6). By July the conditions change in the direction of increased aeration and, as the result of the activity of the micropopulation, a transformation of the acid products into more alkali products and an over-all alkalization of the solod profile take place. In magnitude of pH values (to 4.0-3.5 in the salt suspension) and character of pH dynamics between spring and fall, the upper horizons of solod approach podzolic soils (19). The pH dynamics of the lower horizons of solod, associated with the capillary fringe zone, are due entirely to fluctuations in ground-water level and intensity of evaporation. From the moist periods of the year to the drier periods, we note a certain increase in pH values in the B_1 horizon (which took place in 1957).

Acid decomposition products of plant residue are also formed in the surface horizons in meadow bog solodized soil. At the same time, the strongly alkaline salinized high-standing ground-waters are extended downwards. A combination or mixture of acid and alkaline solutions conceals any set changes in pH between spring and fall. In moist years we see a sharp increase in the pH of the soil. This, obviously, is associated with the irrigation of peripheral or outlying parts of the bog covered by sodium carbonate solonchaks, resulting in an increase in salt content and, especially, of sodium carbonate, in the ground waters beneath the bog.

In solodized solonetz the reaction is strongly alkaline throughout the entire profile, except the upper or top solodized horizons where the reaction is near neutral. In wet years (1957) we note a stronger alkalinity of the soil as a result of the passage of sodium from an exchangeable state to a water-soluble form.

The content of water-soluble substances in the 3 above-mentioned varieties of solodized soils differs (Table 7). Solods contain a small quantity of water soluble substances: the solid residue is not more than 0.08% throughout the profile, increasing somewhat in the A_1 horizon (to 0.17%) owing to water-soluble organic compounds. During the spring, summer, and fall,

Table 5

Exchangeable acidity, meq/100 g of soil (after Sokolov)

Profile No. and soil	Horizon and depth, cm		Total exchangeable acidity	H	Al
338. Solod	A_1	0—10	0,28	0,10	0,18
	A_1/A_2	18—26	0,46	0,03	0,43
	A_2	32—42	0,17	0,03	0,14
		45—55	0,18	0,03	0,15
	B_1	70—80	0,11	0,03	0,08

Note: Comma represents decimal point.

Table 6

Content of ferrous iron, mg/100 g of soil, 1957

Profile No. and soil	Depth, cm	Time of determination		
		May 20	May 25	June 5
338. Meadow solod	0—10	5,00	2,50	1,25
	10—20	3,75	1,25	None
	30—40		None	
	55—65		"	
349. Solodized meadow bog	0—10	10,00	5,65	4,00
	15—25	Traces	None	
	30—38	None	"	
337. Solodized solonetz	0—5	None		
	5—8	"		

Note: Comma represents decimal point.

the total quantity of water-soluble substances hardly changes; only the content of water-soluble humus will fluctuate somewhat, increasing in the spring and decreasing towards the fall. The composition of water-soluble substances in solods is somewhat unusual; despite an acidic reaction we find in almost all the horizons, water-soluble Na, the quantity of which increases somewhat in the illuvial horizons. At the same time we note an increase in these same horizons of the alkalinity and SO_4 ion. Calcium bicarbonates predominate in the salt composition of the A_1, A_1/A_2, and A_2 horizons; sodium bicarbonates are predominant in the B_1 and B_2 horizons. An increase in the content of sodium bicarbonates in the illuvial horizons is responsible for the solonetzization of the soil (Table 7).

There are more water-soluble substances in meadow-bog solodized soil than in solods. This is because they occur in a lowland (flat country) which is a region of salt accumulation from surrounding areas covered by solonetzes and solonchaks. In the upper horizons we find the greatest quantity of water-soluble substances – 0.4%-0.5%; downward throughout the profile the quantity of water-soluble substances decreases gradually (chiefly caused by a decrease in water-soluble humus) and in the lower horizons the water-soluble substance content is about 0.1%. Sodium and bicarbonate and sodium carbonates are predominant among the water-soluble substances; in addition sulfates and sodium chlorides are present. During dry periods of the year we observe an increase in the total salt content in the soil. In the A_1/A_2 and A_2 horizons there is a particularly active accumulation of sodium carbonates, causing solonetzization of the soil. (Table 7). In the spring the meadow-bog solodized soil is leached by waters (Table 2) containing chiefly bicarbonates, sodium carbonates, and having about 1 g/liter mineralization; this, to an even greater degree, contributes to solonetzization and, at the same time, to solodization of the soil.

In solodized solonetz, excluding the actual A_1 surface horizon, we find noticeably more water-soluble substances – up to 0.6% in the B_2 horizon. Between spring and fall, in connection with evaporation of capillary-suspended solutions and drying up of the A_2 horizon, we see a certain increase in the A_2 horizon of salt content, increase in alkalinity from the normal carbonates, and a solonetzization of the soil.

A study of the character of present-day processes and the conditions of their occurrence in solodized soils enables us to draw the following conclusions:

Typical of meadow-bog solodized soil are: an extensive excess of moisture, low ORP values during the first half of the summer plus sufficiently high ORP values during the second half of the summer, and periodic action of mineralized sodium carbonate ground waters.

Solods are also characterized by increased moisture throughout the entire profile (except for 1.5-2 months of the driest time of the year August-September), by an acid reaction of the upper part of the soil profile, by high and homogeneous ORP values throughout the profile during the spring and summer (with a noticeable separation of the A_2 horizon during the driest period), and by a pulsating regime of weakly mineralized ground waters.

Solonetzes differ sharply from these 2 varieties of solodized soils by severe profile desiccation for almost the entire warm period of the year, by similar ORP values throughout the profile, and by temporary effect on the surface horizons of capillary-suspended solutions formed by atmospheric precipitation.

Thus, various processes are presently taking place in these soils, and solodization assumes varied forms.

The bog process is predominant in meadow-bog solodized soil. The solodized horizon is formed under an alkaline medium and a recurring

Table 7

Date on the water extract from solodized soils, meq, 1956

Profile No. soil, and time of soil sampling	Horizon and depth, cm		Alkalinity		C	SO_4	Ca	Mg	Na (spectral)	Adsorbed Na	Solid residue %
			CO_3	Total							
338. Meadow solod, May	A_1	0—10	None	0,24	None	0,04	0,40	0,08	Trace	Not det'd	0,17
	A_1/A_2	10—18	"	0,20	"	0,02	0,25	0,08	"	"	0,03
	A_2	25—35	"	0,16	"	0,02	0,10	0.08	"	"	0,07
		40—50	"	0,20	"	0,04	0,10	None	"	"	0,03
	B_1	53—65	"	0,20	0,14	0,06	0,10	"	0,15	"	0,05
	B_2	70—80	"	0,36	0,20	0,08	0,10	"	0,30	"	0,05
	C	110—120	"	0,44	0,11	0,08	0,10	0,08	0,31	"	0,04
July		0—10	None	0,16	None	0,02	0,40	0,16	0,15	Trace	0,17
		10—18	"	0,16	"	0,02	0,20	0,08	Trace	"	0,03
		25—35	"	0,08	"	None	0,10	0,08	0,06	"	0,02
		40—50	"	0,12	"	"	0,05	0,08	0,07	"	0,02
		53—65	"	0,20	0,08	0,10	0,05	None	0,25	0,92	0,06
		70—80	"	0,24	0,14	0,10	0,05	"	0,31	1,04	0,05
		110—120	"	0,44	0,11	0,08	0,10	0,08	0,32	1,46	0,10
September		0—10	None	0,28	None	0,08	0,40	0,16	0,16	Not det'd	0,17
		10—18	"	0,20	"	0,08	0,20	0,08	0,05	"	0,08
		25—35	"	0,20	"	0,06	0,15	0,08	0,06	"	0,04
		40—50	"	0,20	"	0,04	0,15	None	0,08	"	0,04
		53—65	"	0,28	"	0,08	0,10	"	0,24	"	0,06
		70—80	"	0,32	"	0,08	0,15	"	0,28	"	0,07
		110—120	"	0,40	"	0,08	0,15	0,08	0,30	"	0,05
349. Meadow-bog solodized soil, July	A_T	0—12	0,07	2,19	0,30	1,25	0,10	Trace	3,72	2,80	0,45
	A_1	15—25	0,08	1,62	0,18	0,30	0,31	"	1,74	3,26	0,21
	A_1/A_2	30—38	0,33	2,12	0,18	Trace	0,55	"	1,52	0,20	0,16
	A_2	38—48	0,25	1,62	0,18	"	0,50	"	1,17	0,10	0,14
	B_1	70—80	0,04	1,87	0,18	"	0,36	"	1,61	2,52	0,08
September		0—12	0,08	2,92	Not det'd.				3,00	Not det'd	0,38
		15—25	0,09	1,72	"				1,70	"	0,19
		30—38	0,33	2,40	"				1,61	"	0,20
		38—40	0,27	1,72	"				1,20	"	0,18
		70—80	0,04	1,95	"				1,75	"	0,10
337. Solodized solonetz, May	A_1	0—4	None	0,60	None	None	0,09	0,03	0,63	Not det'd	0,03
	A_2	5—8	0,32	2,52	"	Trace	0,12	0,05	1,85	"	0,24
	B_1	10—20	1,66	4,81	"	"	0,12	None	4,02	"	0,48
	B_2	22—30	2,32	5,61	"	0,10	0,20	0,10	8,59	"	0,65
	B_3	40—50	1,60	3,96	"	0,12	0,07	0,02	5,54	"	0,35
	C	70—80	0,96	3,24	"	Trace	0,10	0,02	3,48	"	0,22
July		0—4	None	0,44	None		0,05	0,03	0,52	1,22	0,03
		10—20	0,43	2,72	0,15	Trace	0,13	0,01	1,96	15,86	0,57
		22—30	2,08	4,88	Trace	0,12	0,21	0,12	7,83	11,07	0,59
		40—50	1,84	3,72	"	0,12	0,07	0,04	5,22	6,08	0,31
		70—80	1,20	3,56	"	None	0,10	0,04	3,81	5,32	0,11
		130—140	1,16	1,76	"	"	0,17	0,09	1,72	0,50	0,06
September		0—4	None	0,44	None	None	0,07	0,02	0,55	Not det'd	0,03
		5—8	0,64	2,64	"	"	0,12	[illegible]	3,48	"	0,36
		10—20	1,97	4,73	0,15	0,12	0,13	0,01	6,74	"	0,55
		22—30	2,32	5,56	0,12	0,15	0,19	0,12	8,26	"	0,62
		40—50	2,08	4,04	0,19	0,15	0,09	0,03	6,19	"	0,34
		70—80	1,20	3,20	0,15	None	0,09	0,04	4,02	"	0,17
		130—140	0,24	1,80	0,15	"	0,15	0,06	1,83	"	0,06

Note: Comma represents decimal point.

action on the soils of sufficiently mineralized sodium carbonate soil ground waters. In "live" solodization is included almost the entire A horizon with the greatest intensity (during the years of observation) in the A_1/A_2 subhorizon. The area of maximum solodization may shift during years of differing moisture conditions. This is why solodization signs are detected in several horizons of meadow-bog solodized soil.

A soil-formation process similar to podzolic is being developed in the top part of the solod having a well-developed solodized horizon under an acid reaction, and with constant leaching by fresh-melted snows. But, at the boundary of separation of the solodized and illuvial horizons we can now see a "live" solodization of the upper part of the illuvial horizon. This occurs as a result of the constant action of upward solutions of weakly mineralized soil ground waters alternating with leaching effect of melted snows.

The formation in solonetz of a solodized horizon is associated with the decomposition of the upper part of the illuvial solonetz horizon by a constant alkaline reaction, and a very temporary excess wetting of the upper part of the profile, (A_1 and A_2 horizons) by capillary-suspended solutions.

Received July 28, 1960

BIBLIOGRAPHY

1. BAZILEVICH, N. I. 1947. Data on the problem of solod genesis. Pochvovedeniye, No. 4.
2. GEDROYTS, K. K. 1926. Solodization of soils Izd. Nosovskoy sel'skokhozyaystvennoy opytnoy stantsii. vyp. 44. otdel agrokhimicheskiy.
3. GORSHENIN, K. P. 1955. Soils of Southern Siberia (from the Urals to Baykal). Izd. Akad. Nauk SSSR.
4. DURASOV, A. M. 1959. Solods and gray forest solodized soils of the forest steppe of Northern Kazakhstan. Pochvovedeniye, No. 1.
5. IVANOVA, YE. N. 1930. Data on the study of solodization processes in forest steppe soils of Western Siberia. Trudy Pochvennogo instituta Vyp. 3-4.
6. KAURICHEV, I. S., V. F. NEPOMILUYEV, and N. N. PODDUBYNYY. 1959. Characteristics of the oxidation-reduction processes in solonetzes and solods. Pochvovedeniye, No. 4.
7. KOZLOVSKIY, F. I. 1959. Anaerobic processes in peat bogs of Central Baraba. Pochvovedeniye, No. 8.
8. KOLESOV, N. A. 1953. Solods and solodized soils of Western Siberia. Dissertation for the candidate's degree in agricultural sciences. Omsk.
9. MOSIYENKO, N. A. 1957. Freezing and melting of soil in the Kulundinskaya Steppe. Pochvovedeniye, No. 1.
10. PODDUBNYY, N. N., and V. F. NEPOMILUYEV, 1957. Biochemical processes in solonetzes and solods during excess moisture. Doklady TSKHA, vyp. 29.
11. POPOV, T. I. 1914. Origin and development of aspen bushes in the Voronezhskaya Guberniya. Trudy Dokuch. pochv. komiteta, vyp. 2.
12. RYBAKOV, M. M. 1939. Solodized soils in the Chernozem zone. Problemy sov. pochv. No. 7.
13. SEMENOVA, N. N. 1958. Exposing certain soil complexes of Northern Kazakhstan by aerial photographs. Pochvovedeniye, No. 8.
14. SERDOBOL'SKIY, I. P. 1940. Influence of moisture on the oxidation reduction processes in podzolic soils. Pochvovedeniye, No. 7.
15. TOLCHEL'NIKOV, YU. S. 1957. The problem of the soils of certain steppe depressions of Northern Kazakhstan. Pochvovedeniye, No. 5.
16. YARKOV, S. P. 1956. Seasonal dynamics of certain soil-formation processes. Pochvovedeniye, No. 6.
17. YARKOV, S. P., YE. V. KULAKOV, and I. S. KAURICHEV. 1950. Formation of ferrous iron and the characteristics of the phosphate regime in sod-podzolic soils. Pochvovedeniye, No. 8.
18. YARKOV, S. P., I. S. KAURICHEV, and N. N. PODDUBNYY. 1956. Experiment in the study of solonetz and solod genesis. Izv. Timir. sel'skokhozyaystvennoy akademii vyp. 2.
19. BOWSER, W. E., J. N. LEAT. 1958. Seasonal pH fluctuations in a grey wooded soil. Canad. J. Soil Sci. v. 38, 28-133.

SPECIFIC RESISTANCE OF GREY FOREST SOILS DURING PLOWING IN THE PAKHOMOVO SOVHOZ, TUL'SKAYA OBLAST'

P. U. BAKHTIN and V. I. VOLOTSKAYA, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

Soil-geographic, agricultural chemical and physical studies were conducted by the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR, at the "Pakhomovo" sovkhoz in order to work out methods for mapping soils on a large scale. Studies were also begun in 1958 on the physico-mechanical and technological properties of soils: the optical moisture of soils during cultivation; the specific resistance of soils during plowing; hardness; shear strength of soil, internal and external friction; plasticity; stickiness, etc.

Most of these properties have been determined from the genetic horizons of the principal soil subgroups under changing crop practices and a varying soil moisture.

These studies enable us to compile cartograms on the specific resistance of soils during plowing, and to have basic mechanical soil indicators necessary for estimating the sturdiness of soil cultivating implements.

In this article we shall touch on: 1) the optimum moisture required for cultivating these soils, and 2) the specific resistance of soils during plowing.

We conducted our studies in a region of widespread grey forest soils which, according to Rozov's (11) data, occupy 44% of the territory of the Tul'skaya Oblast'. (the northern part and a small area of the west).

V. V. Dokuchayev (3) was the first to separate this zone. The zone covers large areas of plowed soils between the podzolic and chernozem zones.

According to Troitskiy's data (13), the principle areas in the region of the "Pakhomovo" sovkhoz are covered by the following groups of soils: the first area, by light-grey forest soils with a varying degree of podzolization and gleying; the second area, by grey forest soils with signs of surface gleying: the third area, by grey forest soils with signs of subsoil gleying and by grey forest soils with gley sub-soil.

The humus content in the plowed layer of the first two soils, which cover the largest areas of the sovkhoz, is 2%-2.5%, profile numbers 572, 567 (13). The humus content decreases sharply with depth. In isolated spots we find a second humus horizon. The content of absorbed cations Ca^{++}, and Mg^{++} in the plowed layer is about 10-15 meq.; the salt pH is about 5. Podzolization is expressed in the form of an intensive white powdering of soil aggregates. The thickness of the humus horizon varies between 25 and 30 cm. The illuvial horizon is clearly developed.

In the third group of soils situated usually in areas with high ground waters (2-4 m) the humus content in the 0-10 cm layer, according to Troitskiy's data (13), varies between 3% and 3.7% (Profile No. 200). The adsorbed cations in the 0-5 cm and 24-29 cm layers total 15.9 and 23.1 meq, respectively. These soils in a moist state are dark. From the description by Troitskiy (13) and his colleagues, the grey forest soils with gleyey subsoil have a grey, blocky to powdery A_{plowed} layer, 0-25 cm thick, which passes abruptly into the 25-42 cm A_1 horizon, which is dark-grey, almost black, and has a granular structure and a light grey powdering throughout the faces of the structural units.

The soil of the individual fields on the Shevernyayevo farm and Vysokoye farmstead, where we made our study, is complex. We may find on the very same field several soil varieties by subgroups and by the erosion state of the plowed layer. The relief is undulating with a sharply expressed microrelief.

As we see from Table 1, coarse silt (0.05-0.01 mm in diameter) is the predominant fraction. From Kachinskiy's classification (5), the soils belong to the fine clay loam, coarse silt group. There is noticeably more clay in the grey forest soils with gleyey sub-soil than in the light grey forest podzolized soil, which is associated with the different formation conditions of these soils.

Maximum hygroscopic moisture in the light-grey forest podzolized soil (Profile No. 3) is in the plowed layer 4.1%-4.5%, in the grey forest soils 5.2%-5.5%; the minimum or field moisture capacity for these soils equals, correspondingly, 32%-33%. As we see, there is between the maximum hygroscopic moisture and field moisture capacity a great range of

Table 1

Data on the particle-size analysis of soils after the Kachinskiy method

Depth, cm	Loss during HCl treatment	Particle diameter, mm						
		1,0—0,25	0,25—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001	Total particles < 0,01
Light grey forest podzolized. Profile No. 38								
0—5	3,78	1,74	3,96	43,60	14,36	14,36	18,20	46,92
18—23	1,52	1,80	3,52	51,52	15,04	14,84	11,76	41,64
Grey forest podzolized. Profile No. 567								
0 — 5	2,9	2,5	2,4	44,6	24,7	6,1	16,8	47,6
25—30	3,0	3,1	2,8	43,0	20,6	13,0	14,5	48,1
Grey forest with gleyey sub-soil. Profile No. 200								
0 — 5	2,3	2,4	0,7	51,2	11,0	10,8	21,6	43,4
24—29	1,8	0,8	1,1	47,3	9,2	8,8	31,0	49,0

Note: Comma represents decimal point.

available moisture, amounting to about 25%-29%. This positive quality in these soils is explained, in our opinion, by the unique distribution in them of separates (predominantly coarse silt).

In connection with moisture properties, a knowledge of the optimum soil moisture required for the soil's mechanical cultivation is of great interest. The moisture of initial sticking is the upper limit of soil moisture after which the quality of the plowland suddenly deteriorates and the mechanical energy consumed in plowing, according to Kachinskiy (7), increases. The moisture of the lower limit of the soil's plasticity is of great importance in determining the optimal moisture during soil cultivation. Studies have shown that the tendency toward deformation of clay and clay loam soils increases sharply with their transition from a semi-hard to plastic state. We assume that the lower plastic limit may be used as the boundary separating the two soil states, with a high and low rate of deformation. The stickiness of clay and fine clay loam soils begins to become apparent, as a rule, when the moisture is somewhat lower than the lower plastic limit in the medium and coarse clay loams, and also in the sandy loam soils when the moisture is somewhat greater than the lower plastic limit.

The highest quality of plowland and the minimum energy consumption required to produce it (according to Kachinskiy) are observed when the moisture is 2%-3% less than the moisture of the initial sticking of the soil to cultivation implements (?). At this time the soil does not stick to the implements, but the stickiness within the soil contributes to the aggregation of soil particles. In connection with the fact that the stickiness of coarse clay loams and sandy loams is above the lower plastic limit, the range of optimum moisture is considerably broader for coarse-textured soils than for fine-textured soils.

Table 2 gives data on the plasticity of soils studied. The lower plastic limit of light grey forest podzolized soils (spring wheat stubble), where a dynamometer study was made, fluctuates around 20% absolute moisture or 60%-66% relative moisture. It increases to 21%-23.5% absolute moisture or to 64%-66% relative moisture on clover plots in the 0-20 cm layer, which, obviously, is due to the large aggregation of soil beneath perennial grasses. Consequently, the soils beneath perennial grasses can be cultivated with greater moisture than the old plowed soils.

The plastic number, in connection with an increase in its upper limit, increased noticeably on the plot, where, in 1946, clay had been plowed up — onto the soil surface after the Bushinskiy method (1). This implies a great clayiness of the soil after its "radical alteration."

The lower plastic limit was somewhat higher on the plot of grey forest soils with gleyey sub-soil (deeply humified) where the soil had undergone radical alteration after the Bushinskiy method, than in light grey soils and equals 21%-22% absolute moisture.

Data on the determinations of stickiness in light grey forest podzolized soil under second year clover, assigned by Kachinskiy to the medium sticky soil group, is given in Table 3.

Considering the plastic and sticky indicators of light grey forest podzolized soils of the "Pakhomovo" sovkhoz, the optimum absolute moisture required for their cultivation under stubble of previous crops is equal to about 19%-20%, on the soil of perennial grasses — 21%-22%. This limit drops to 17%-18% on so-called radical alteration plots after Bushinskiy; for grey forest soils with gleyey sub-soil (humified) it equals approximately 21%-23%. Under production conditions the upper

Table 2

Plasticity of soils of the "Pakhomovo" sovkhoz

Soil, field number and preceding cultural practices	Depth, cm	Lower plastic limit or boundary of rolling-out		Upper plastic limit		Plastic number after Aterberg, in absolute %
		Moisture, %				
		Absolute	Relative	Absolute	Relative	
Light grey podzolized fine clay loam, coarse silt soil. Field No. 7. Oats stubble	0— 5	21,7	65,2	31,9	95,8	10,2
	5—10	20,6	57,9	31,2	87,7	10,6
	15—20	20,3	62,9	30,6	94,8	10,3
	20—30	19,3	65,7	29,7	101,0	10,4
Same. ... Field No. 8. Second year clover	0—10	23,5	66,4	33,1	93,5	9,6
	15—20	20,8	64,4	31,6	97,9	10,9
	20—30	18,8	58,2	28,7	88,9	9,9
Same, but plowed with a subsoil plow, after V. P. Bushinskiy, to 50-60 cm with soil turned over. Field No. 5. Oats stubble.	0—10	19,7	55,8	33,5	94,9	13,8
	10—25	20,3	63,0	34,0	105,3	13,7
	25—40	19,8	78,6	32,3	128,2	12,5
Grey forest gleyey-sub soil (after "radical alteration"). Field No. 5. Oats and pea stubble	0—10	20,8	58,8	36,0	102	9,8
	10—20	22,9	70,9	34,7	107,5	11,8
	20—30	21,2	65,7	36,1	111,8	14,9

Note: Comma represents decimal point.

Table 3

Stickiness of light grey forest podzolized soil. Field No. 8. A_{plowed} layer (0-20 cm)

Moisture, %		Stickiness, g/cm²
Absolute	Relative	
22,3	70,0	0,05
27,9	83,8	1,26
29,2	87,7	2,14
29,6	88,9	2,52
34,0	102,1	2,77

Note: Comma represents decimal point.

moisture limit of fine and medium clay loam soils (soil of perennial grasses) may increase during cultivation by 1%-3%, but no higher than the lower plastic limit; for coarse clay loam and sandy loam soils it may be increased considerably.

If we compute the upper limit of optimum moisture required for cultivating soil based on indicators of soil stickiness, plasticity, visual observations on plowing, the lower moisture limit will be, for the time being, determined approximately by the cloddiness of the plowland, etc.

As Kachinskiy's data (7, 8) revealed, the restriction of the lower limit of soil moisture by a coefficient varying between 1 and 1.75 of maximum hygroscopic moisture in the various soils (10) has not solved this problem either (especially for the grey forest and sod podzolic soils). In general, we must point out that, despite numerous discussions in our country and abroad on the problem of determining the upper and lower limits of soil moisture required for cultivation, these limits (particularly the lower moisture limit) have, as yet, no "constant" characteristics, which take into account the various soils, soil cultivating implements, their operation rate, and the different cultivation depths. This exceptionally important problem for agriculture should be solved scientifically in the near future. Without such a solution, a rapid soil cultivation, which will be put into practice more and more in the already begun 7-year period, cannot be accurately worked out.

The specific resistances of soils were determined by the P-5-35M plow (5 furrow tractor plow) with skim-coulters drawn by the diesel motor tractor DT-54 in second gear. A traction hydraulic dynamograph designed by the All-Union Scientific Institute for Research in Farm Machinery (VISKHOM) (a) type 1A, and a traction tractor calibrator designed by Korobochkin (RTTK — Agricultural Physics Research Institute) were used (9). The depth of plow travel during the dynamometer study varied widely.

Table 4

Specific resistance of soils

Soils, field number, and previous cropping practices	Soil moisture %				Depth of plow, cm	Repetition	Traction resistance of the plow, kg	Specific resist. of the soil, kg/cm²
	0—10 см		10—20 см					
	Absolute	Relative	Absolute	Relative				
Sept. 6. light grey forest podzolized fine clay loam coarse silt. Field No. 8. Soil of second year perennial grasses	20,1	59,3	19,4	61,0	14,0	3	2420	0,82
	20,8	61,4	19,4	61,0	17,6	2	2480	0,66
	19,9	58,7	18,7	58,8	19,1	3	2497	0,64
	20,6	60,8	17,5	73,9	24,0	5	3058	0,60
Sept. 2, 3 and 10. Soil the same. Field No. 7. Oats stubble.	20,5	60,5	20,20	63,5	20,1	12	2375	0,57
	20,7	60,7	18,6	78,5	22,0	19	2440	0,53
	21,4	63,1	20,8	87,8	23,6	6	2381	0,50
	20,4	60,2	16,9	71,3	25,8	3	2612	0,50
Sept. 10-13. Same soil and cropping practices. Field No. 5 (A).	18,5	54,6	17,8	55,8	20,0	1	2020	0,48
	23,3	68,7	17,6	74,3	21,0	1	1970	0,45
	19,8	58,4	17,3	73,0	23,0	6	2118	0,44
	19,8	58,4	18,5	78,1	24,7	3	2272	0,45
	18,5	54,6	15,1	63,3	26,3	1	2360	0,42
Sept. 20-23. Preceding cropping practices and soil the same. In 1946 deep plowing, after Bushinskiy, to 50-60 cm, in the following years ordinary plowing to 20-22 cm. Field No. 5 (B).	19,8	58,4	20,8	65,4	16,1	1	2660	0,76
	19,3	56,9	20,1	63,2	17,9	7	2625	0,66
	18,6	54,9	20,0	84,4	21,0	5	2852	0,64
	19,1	56,4	20,2	85,3	24,3	1	2970	0,68
	19,8	58,4	20,9	88,2	27,8	1	3100	0,59
Sept. 18. Grey forest soil with gleyey subsoil (dark-colored). In 1946 deep plowing, after Bushinskiy, in the following years ordinary plowing. Field No. 5 (C). Pea and oats stubble.	21,5	60,6	23,5	92,5	24,3	8	2698	0,53
	21,1	59,4	20,7	81,5	26,3	3	2937	0,53
	23,1	65,1	28,2	111,1	27,5	1	2680	0,46
Sept. 17. Grey forest soil with gleyey (dark-colored). Field No. 6. Sunflower for silage.	20,7	58,3	20,7	81,5	23,2	4	2450	0,51
	20,8	58,6	18,5	72,8	24,4	5	2488	0,49
	21,9	61,7	19,8	77,8	25,4	6	2386	0,45
	22,3	62,8	18,3	72,0	26,7	1	2440	0,44
Sept. 28. Grey forest soils with signs of surface gleying. With a double humus horizon. Field No. 8. Winter wheat stubble. "Vysokoye" farmstead.	28,7	80,9	27,7	109,1	20,6	3	2045	0,48
	27,8	78,3	22,8	89,8	21,6	3	1933	0,43
	28,7	80,9	26,5	104,3	23,2	2	2060	0,43

---

[a] Wherever the depth of plowing was more than 20 cm, the soil moisture is given for the 20-30 cm layer and not for the 10-20 cm layer.

[b] In designating soils, we are following the classification scheme for soils of the "Pakhomovo" sovkhoz, as proposed by Troitskiy (13).

Note: Comma represents decimal point.

Table 4 gives specific resistance indicators r soils on the experimental areas of the akhomovo" sovkhoz, the Shevernyayevo Farm, and on areas of the "Vysokoye" farmstead with various soils and previous crops in 1958.

The soils, plowed by a subsoil plow, after the Bushinskiy method, to a depth of 50-60 cm, were, at first, very difficult to cultivate by ordinary means, because the clay illuvial horizon had been plowed up onto the surface, while the plowed humus layer was laid somewhat deeper and, consequently, the areas were abandoned for several years. In recent years these areas were plowed for agricultural crops, but even until now the cultivation of these soils has been extremely difficult. It is especially difficult to cultivate the light grey forest podzolized soils, which, at the surface, present a thoroughly untillable structureless clay (Field No. 5). Deep plowing of grey forest soils with gleyey subsoil (fairly deeply humified) did not lead to a noticeable deterioration of their physical properties, as in the preceding case.

We determined the specific resistances of all soils typical of this region and of soils which have been subject to so-called radical alteration. Included are the basic previous cropping practices: perennial grasses, winter and spring wheat stubble, and row crops. As we can see by analyzing Table 4, the dynamometer study was made when the moisture approaching the optimal moisture required for soil cultivation, was primarily within limits of 17.5%-20.5% of the absolutely dried weight of soil. As far as the other areas were concerned, moisture was somewhat lower at the depth of plowshare on Field 5 (B). There was a noticeable increase in soil moisture on the area of the "Vysokoye" farmstead beneath winter wheat stubble — the moisture exceeded optimum moisture by 3%-5%; but at the depth of plowshare it was equal to the optimum moisture and no sticking on the moldboard took place. The excess moisture in the upper layer had a greater effect on the operation of the tractor, the caterpillar tracks of which made severe impressions in the soil. A fairly rapid drying-up of the soils of the "Pakhomovo" sovkhoz after periods of rain was observed. The entire month of September was favorable for fall plowing; only at the end of the month was the moisture in the soil, in spots, above the optimum value.

We shall begin with the specific resistance characteristics of light grey forest podzolized soils having signs of surface gleying from the soil area of perennial grasses. The maximum specific resistance — 0.82 kg/cm² was recorded when the plowing depth was 14.0 cm, and the minimum specific resistance — 0.60 kg/cm² when the plowing depth was 24 cm. According to Shchuchkin's (15) classification these indicators are associated with medium heavy and heavy resistances. The specific resistance decreased with an increase in the plowing depth. However, the total traction resistance of the plow increased from 2420 to 3058 kg, having surpassed in this latter instance the standard showings of the DT-54 tractor in first gear.

This is a very interesting aspect of the matter which is not often taken into account in production: the assumption that resistance is increased with subsoiling at the same time as the total traction resistance of the plow is increased. An increase in specific resistance is observed only when the compaction and hardness of the soil increases with subsoiling (or increase of top soil). To explain why the specific resistance may decrease when the total traction resistance of the plow increases, let us examine the formula of V. P. Goryachkin on the traction force of plows: $P = fG + K_0ab + Eabv^2$ where P — is the traction force of the plow in kilograms; f — the drag coefficient of the plow in a furrow; G — the weight of the plow; a — the plowing depth; b — the plow width; K_0 — the soil deformation coefficient for a unit of areas of cross-section of the soil: v — the rate of plow operation in meters per second, E — the coefficient describing the effort required by the plow to cast the soil aside

Without going into an analysis of all the terms of Goryachkin's formulas, we shall dwell

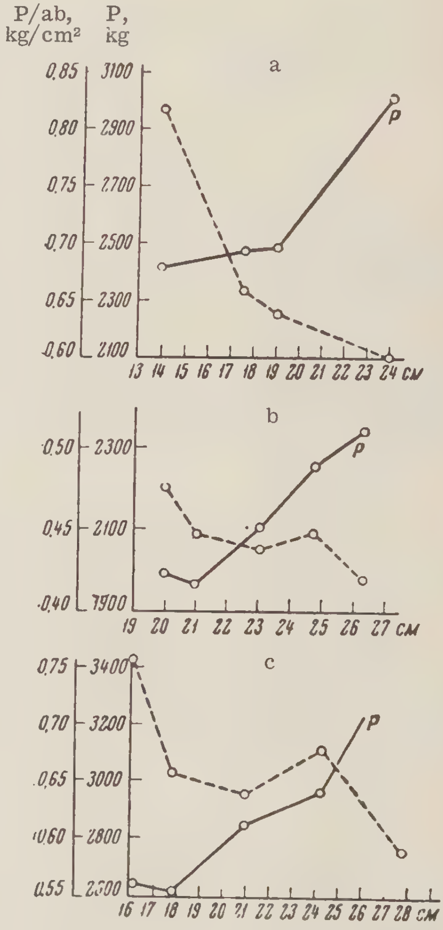


Fig. 1. - Change in the specific resistance of soil K_1 = P:ab and traction resistance of the plow P as a function of the plowing depth of light grey, forest, fine clay loam, coarse silt soil.
a - clover and second year timothy; B - oats stubble on a fall-plowed field; C - same; deep plowing, 1946.

on the K_0 coefficient, which is important in actual practice. This coefficient describes the main part of the plow resistance required for soil deformation. Relying on numerous experiments, the author of this formula concluded that plow resistance is a linear function of the area of cross-section of the soil[1] (and depth). A deviation from this pattern may be due to the effect of a variable soil resistance in connection with the different depth of previous plowing; this is, when a more compact or friable subsoil is involved.

By examining the first term of Goryachkin's formula — $\underline{fG}$, representing the so-called "dead" resistance, which depends upon the weight of the plow $\underline{G}$ and the coefficient $\underline{f}$ and independent of the plow depth, and the second term — K_0 ab, directly proportional to the plow depth with a given plow width, we arrive at the following conclusion: the total plow resistance for one square centimeter of cross-section decreases with subsoiling when the plowed layer is similar. This is the case, because in a homogeneous plowed layer the soil deformation coefficient K_0 remains the same, while the deformation effort increases only from the cross-section of soil. At the same time, the dead resistance of the plow $\underline{fG}$, independent of the cross-section of soil, will be distributed over an entire large area as the cross-section of soil increases. Therefore, in shallow plowing which creates a small cross-section of soil, the "dead" resistance, remaining unchanged, but relatively large, will increase the total specific resistance K_1, occurring on a unit of cross-section of soil, if we compute it according to the simplified equation: $P=K_1 a\cdot b$, or $K_1=\frac{P}{ab}$. In this formula the coefficient K_1, in contrast to the deformation coefficient K_0 in the second term of Goryachkin's equation, includes not only the effort required for soil deformation, but also the efforts exerted in dragging the plow — the "dead" resistance $\underline{fG}$, — and in casting the soil to one side.

Based on the foregoing, the specific resistance should decrease with an increase in the depth of plowing, when we have a homogeneous compact soil, which is seen in our case on the soil of perennial grasses. Accounting for these peculiarities in the investisoils is of a great importance. Not only the data of Goryachkin, but that of Seleznev (12), Furman (14), and others, are evidence that on homogeneous compact soils the specific resistance decreases with depth during plowing.

The change in the specific resistance of the soil $\frac{P}{ab}$ and in the traction resistance of the plow as a function of the plow depth is shown in Figure 1 A. With an increase in the depth of plowing, given the same plow width, the traction resistance of the plow $\underline{P}$ is increased as a straight line, whereas the specific resistance $\frac{P}{ab}$ decreases. On field No. 7 with the same soils beneath oats stubble the specific resistance is basically associated with mean values hovering about 0.50 kg/cm². Only at the minimum depth of 20 cm does specific resistance equal 0.57 kg/cm². On field 5(A) with the same soils we observe somewhat lower values in the specific resistance of soils during plowing — 0.48 — 0.42 kg/cm² than on fields No. 8 and No. 7. The plow depth changed, accordingly, from 20 to 26 cm.

The graph in Figure 1-B shows the change in the specific resistance of the soil $\frac{P}{ab}$ and the traction resistance of the plow when the plow depth increases. We see the same pattern which exists on the previous fields 8 and 7.

Table 4 gives the specific resistance indices of the same soil on field No. 5 (b), plowed in 1946 by a subsoil plow to a depth of 60 cm following the Bushinskiy method. In 1958 oats were planted here by plowing the field in the fall to 20 cm. In connection with the sudden deterioration in the physical properties of the plowed layer after deep plowing, we recorded a sharp increase in the specific resistance of the soil, which changed from a medium resistance to a medium heavy and heavy resistance.

The specific resistance decreased from 0.76 to 0.59 kg/cm² when the plowing depth increased from 16.1 to 27.8 cm, while the traction resistance increased from 2660 to 3100 kg. The pattern in this case stood out in sharp contrast to the previous one, because the plowshare in individual places penetrated the sod humified layer piled edgewise by the plowed subsoil, when the plowing depth was over 20 cm. The tractor operated unevenly, in jerky motions, on the radically altered areas and, in several places turned and slid (Figure C).

On field 5(C) under peas and oats on grey forest soils with gleyey subsoil and a deep dark-grey humified horizon, deep plowing (1946) likewise increased the specific resistance but less than on the light grey forest podzolized soils. When the plowing depth increased from 24.3 to 27.5 cm, the specific resistance decreased from 0.53 to 0.46 kg/cm². On the same soil under sunflower on Field No. 6 the specific resistance changed from 0.51 to 0.44 kg/cm² with the increase in the plowing depth from 23.2 to 26.7 cm.

On the "Vysokoye" farmstead, field No. 8 containing grey forest soils with signs of surface gleying and with a double humus layer was covered with a winter wheat crop. A dynamometer study of the plow revealed minimum specific resistance values for the soil, varying within limits of 0.43-0.48 kg/cm².

The general pattern of decrease in specific resistance of soils with an increase in the plowing depth is confirmed also by data on the bulk density of soil, which we determined on the individual strips where we made our dynamometer study. This data is given in Table 5.

---

[1] According to the latest data obtained by Kapparini (4) this is observed only to a depth of 45 cm. Further subsoiling upsets this pattern because the effort being exerted in casting the soil aside increases sharply.

Table 5

Change in the bulk density of soil at various depths, g/cm³

Area		Depth, cm					
		0–5	5–10	10–15	15–20	20–25	25–30
Field No. 8, perennial grass sod		1,40	1,41	1,39	1,35	—	1,38
Field No. 7, oats stubble		1,16	1,18	1,20	—	1,26	1,41
Field No. 5. Cultivation in 1946 after Bushinskiy	Oats stubble on light grey podzolized soils	1,31	1,46	1,36	—	1,39	1,30
	Oats and pea stubble on grey forest soil with gleyey subsoil	1,25	1,33	1,42	1,36	—	—

Note: Comma represents decimal point.

We see from Table 5 that the bulk density of soil on the four areas at the depth of plowshare operation did not increase, as was sometimes the case with compact and hard subsoil. On the contrary, it decreased, which, together with the excellent blocky-granular structure of the subplowed layer, led to a decrease in the specific resistance of soils during plowing.

If we compare the shape of the specific resistance curves on all 3 graphs and especially on the second and third, with flucutations in the bulk density of the soil, we see that the specific resistance varies widely in the range of bulk density by depth. Wherever it increases, the curve of specific resistance rises upward sharply; the curve of specific resistance also drops more abruptly when the specific resistance decreases sharply with depth.

Conclusions

1. These are the first results of determining the specific resistance of soils of the "Pakhomovo" sovkhoz during plowing: a) of light grey forest podzolized soil beneath second year perennial grasses and on oats stubble; b) of grey forest soil with gleyey subsoil under peas with oats and sunflower for silage, c) of grey forest soil with a double humus layer and with surface gleying under winter wheat for green forage; d) on an area of light grey soil and grey soil with gleyey subsoil after deep plowing following the radical soil alteration method (after Bushinskiy).

2. When the moisture of the soil equals or approaches the optimum moisture, the maximum specific resistance values are obtained on clover area, and against a background of deep plowing, on light grey forest podzolized soils. These values are in category of medium heavy and heavy specific resistance (0.60-0.82 and 0.59-0.76 kg/cm²). On the remaining areas the specific resistances of soils are medium. On light grey forest soils, in connection with their inferior state of cultivation, the specific resistances during normal moisture are higher than on the grey forest soil with gleyey subsoil. The minimum specific resistance indices are recorded on grey forest soils with a double humus horizon (0.43-0.48 kg/cm²).

3. With subsoiling, despite an increase in the total traction effort registered on the tractor bar, the specific resistance of the soil decreased on all areas, as a result of the high state of soil cultivation, decrease in the hardness of the subplowed layer, and its lower bulk density.

4. The upper limit of optimum moisture required for cultivating light grey, forest, podzolized, and grey, forest soils with subsoil-gleyey has been determined.

Received June 30, 1959

BIBLIOGRAPHY

1. BUSHINSKIY, V. P. 1942. Radical alteration of soils as a basis for establishing their effective fertility. Sbornik pamyati akad. V. R. Vil'yamsa. Moscow and Leningrad Izd. Akad nauk, SSSR.
2. GORYACHKIN, V. P. 1937. Traction force of tractor plows. Complete works Vol. III. Sel'khozgiz.
3. DOKUCHAYEV, V. V. 1949. Our steppes then and now. Selected works. vol. II. Sel'khozgiz.
4. KAPPARINI. 1958. Effect of the depth and width of furrow, and total rate of resistance to plow movement. Sel'skoye khozyaystvo za rubezhom. No. 8.
5. KACHINSKIY, N. A. 1958. Methods of studying the particle-size and micro-aggregate composition of soil. Izd. Akad. nauk, SSSR.
6. KACHINSKIY, N. A., A. F. VADYUNINA, and Z. A. KORCHAGINA. 1950. Experiment in the agricultural physical characteristics of soils based on the example of the Central Urals. Izd. Akad nauk SSSR. Moscow and Leningrad.

7. KACHINSKIY, N. A. 1934. Experiment in the agricultural meliorative characteristics of soils, Part I, Izd. sovetsk. sektsii. MAP.

8. KACHINSKIY; N. A. 1937. Soil properties as a factor determining the work requirements of soil cultivating machinery. Pochvovedeniye, No. 8.

9. KOROBOCHKIN, I. V. 1956. Apparatus for automatically registering traction forces and plowing depths. MSKH-VASKHNIL. AFI. Byul. nauchno-tekhnich. inform. po agronom. fizike. Leningrad. No. 2.

10. PIGULEVSKIY, M. KH. 1936. Principles and methods in an experimental study of soil deformations. In the collection of VISKHOM. Teoriya, Konstruktsiya i proizvodstvo sel'sko — khozyaystvennykh mashin. t. 2.

11. ROZOV, N. N. 1939. Soils of the central forest steppe. Pochvy. SSSR. Vol. III, Moscow and Leningrad. Izd. Akad. nauk, SSSR.

12. SELEZENV, V. P. 1934. Mechanization of agriculture. Sel'khozgiz.

13. TROITSKIY, A. I. 1958. Grey forest soils of the northern Srednerusskaya uplands. Putevoditel'. First session of soil scientists. Izd. Akad. nauk, SSSR.

14. FURMAN, L. 1937. A rational soil cultivation system as a basis for high labor productivity on tractor aggregates. Sots. rekonstr. sel'skogo khozyaystva No. 1.

15. SHCHUCHKIN, N. V. 1952. Plowshares and surface plows. Mashgiz.

COBALT ABSORPTION BY PLANTS IN RELATION TO THE HUMUS CONTENT IN SOIL

N. V. KULIKOV, Institute of Biology, Ural Branch of the Academy of Sciences, USSR

A study of chemical elements found in microquantities in the soil-plant system is, apart from the general biogeochemical sense, of substantial interest in connection with the problem of microelements. Resolving this problem requires not only a careful study of the biological role of these or other microelements, but also a knowledge of the patterns of their behavior under various conditions of biogeocoenosis (1, 2, 8). The results of such research have recently assumed great importance with respect to possible radioactive contaminations of individual sections of the earth's surface and the problem of deactivating them (9).

Cobalt is one of the elements extremely interesting in this regard. Its radioactive isotope—Co^{60} is presently being widely employed in various branches of industry, medicine, agriculture, and in several other fields of human endeavor, which may lead to accidental accumulations of it in various areas, as a contamination agent of soil and vegetation. The stable cobalt isotope is a microelement which plays an important role in the life of animals and plants (3, 6, 11). We know that cobalt belongs to a group of elements which are stably sorbed by soil particles, which explains its extremely weak mobility in soils and its low availability to plants (4, 7, 10). Soil liming decreases the intake of this element into plants (12); application to the soil of such complex compounds as EDTA (ethylenediaminetetraacetic acid) or the ready complex Co-EDTA increases tenfold Co^{60} intake into plants and one-hundred fold its content in the soil solution (5).

This report presents data on experiments in studying Co^{60} absorption from the soil by plants with various amounts of humus in the soil.

Experiments were replicated twice with vetch and oats in 8 kg capacity containers out in an open area. The original soil was a well-cultivated meadow chernozem-like soil (humus after Tyurin—13.1%; pH=6.6), which was in various treatments diluted by leached lake sand or enriched by humus. As a result, the treatments on total humus content (in percent of dry weight of soil) were as follows: 1-13.1, 2-5.1, 3-3.4 and 4-16.9. A solution of $Co^{60}\,Cl_2$ equal to 48.75 microcuries per 1 kg or 390 microcuries per container was applied to each soil mixture prior to planting. The weight of the cobalt applied with a radioactive compound was 3.03 mg for 8 kg of soil. The original soil without any radiocobalt[1] was used as a control for determining the effect of applied dosage on plant growth. After planting, visual observations were made during the entire growing period of plant growth, while 10, 20, and 50 days after germination, as well as harvest, plant samples were taken from all treatments so as to study radioactivity. The radioactivity of ashed compounds of various plant parts was measured with the B-2 equipment under a BFL-T-25 type count-tube or counter. With the harvest at the end of the growing period, we took into account (by careful washing and thermostat drying to constant weight) apart from the plant tops, the plant roots, which enabled us to reexamine the labelled cobalt accumulation by plants in the various treatments, in percent of applied dosage.

Visual observations during the growing period showed that the radiocobalt dosage which we selected had no overpowering effect on plant growth. We can clearly see this from the data in Table 1, where the basic results of harvest and processing the experiment at the end of the growing period are set forth. We see from Table 1, too, that the dilution of the initial soil by sand did not substantially affect the total plant biomass, whereas the addition into the soil of humus noticeably increased not only the top weight but also the root weight. We can clearly see from the data on plant radioactivity for 1 g of dry matter a difference in radiocobalt accumulation (especially of the root system) in the various experimental treatments. As the initial soil is diluted by sand, the radioactivity of plants increases. However, with the addition into the soil of humus the radioactivity decreases sharply; in the tops of vetch the accumulation of radiocobalt is several times greater than in the top of oats. Recovery of radiocobalt from the soil by plants (expressed in percent of amount applied) depends upon the extent to which the soil is deficient in humus and also upon the weight of the plant biomass, and ranges, for oats, from thousandths to hundredths and, for vetch from hundredths to tenths of a fraction of a percent.

---

[1] The author uses the word "radiocobalt" for cobalt having a ratio (as indicated in the text) between the weight of the element and radioactivity (Editor's note).

Table 1

Dry weight (in g), radioactivity of 1 g of dry matter (in counts/min), and total radioactivity (in % of applied dosage) of the principal parts of oats and vetch, from treatments with the final harvest of the experiments

Indices		Control without radiation	Treatments			
			1	2	3	4
Oats						
Dry weight	Tops	40,5	52,1	59,1	48,7	170,5
	Roots	5,8	5,8	5,8	5,0	17,3
Radioactivity per 1 g	Tops	—	13	20	20	8
	Roots		1930	2480	7250	290
Total radioactivity	Tops	—	0,007	0,012	0,011	0,012
	Roots		0,12	0,16	0,40	0,056
Vetch						
Dry weight	Tops	43,5	60,8	54,5	57,8	85,3
	Roots	5,9	5,8	4,1	4,4	6,7
Radioactivity per 1 g	Tops	—	90	160	180	18
	Roots		1800	3200	4000	450
Total radioactivity	Tops	—	0,061	0,098	0,11	0,017
	Roots		0,11	0,15	0,20	0,033
Humus after Tyurin, %		13,1	13,1	5,1	3,4	16,9

Note: Comma represents decimal point.

Figure 1 shows the radioactivity of 1 gram of lry tops of oats and vetch at different growing eriods. Here we see especially well the foregoing marked difference in radiocobalt accumuation between the two plant species, and by reatments. In addition, the diagram shows hat radioactivity per unit of plant weight dereases noticeably toward the end of the growng period. If we express the accumulated adioactivity for the weight of one plant during he various growing periods, as is done in igure 2, we see that radiocobalt absorption by lants continues up to the end of the growing eriod. Table 2 gives the results of radiocobalt ccumulation in various parts of plants which ave completed their growing cycle of developnent. Since the general type of isotope distriution in the plants of various treatments did ot change, the table gives mean data from all reatments and replications. We see from able 2, that radiocobalt is mostly accumulated n the plant roots; in addition, radiocobalt content in the roots of oats and vetch is approxinately the same. There is considerably less adiocobalt intake in the plant tops, but there s a greater radiocobalt accumulation in vetch han in oats. Radiocobalt distribution through-ut the vetch tops is more uniform than in oats; here is a somewhat greater radiocobalt acumulation in the leaves than in the other parts f plants.

Summarizing, we might point out that on oarse-textured soils, with less organic matter, lants are capable of accumulating more radiocobalt than on soils which are rich in organic matter. The recovery of radiocobalt from the soil by plants depends upon the specific (by species) composition of vegetation as well as upon that biomass which is able to develop a phytocoenosis during the growing period. For the two plant species which we studied the total radiocobalt removal by the tops (in percent of amount applied) was not more than hundredths of a fraction for oats or more than tenths of a fraction for vetch. These data agree well with the results which we obtained in other experiments and again shows that cobalt applied to the soil is converted into forms slightly available to

Table 2

Co^{60} distribution in oats and vetch at the end of the growing period (mean data from all treatments)

Parts of plants	Counts per minute for a g of dry matter	
	Oats	Vetch
Seeds	4	110
Bean pods	—	124
Leaves	40	140
Stems	18	100
Roots	2990	2360

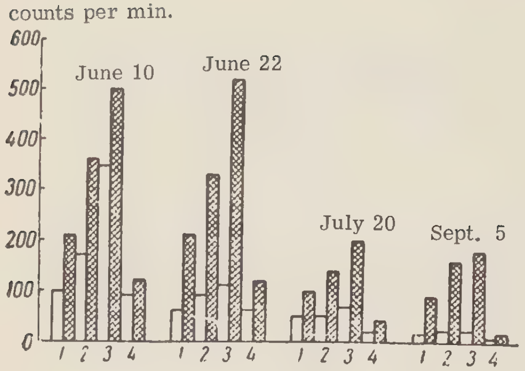


Fig. 1. - Cobalt content in oat tops (not crosshatched) and vetch tops (crosshatched) by treatments (1,2,3,4) during different growing periods (counts per min per 1 g of dry matter).

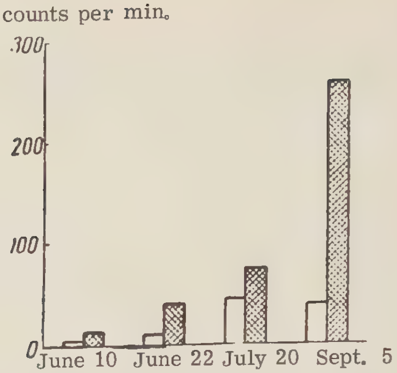


Fig. 2. - Cobalt content in tops of oats (not crosshatched) and vetch (crosshatched) at different growing periods (counts per minute for 1 plant). Mean data from all treatments and replications.

plants (4, 5). It was noted that there was more radiocobalt per unit of plant weight during the initial phases of the growing period than at the later periods, although radiocobalt uptake by plants did not cease during the entire growing period. The cobalt absorbed by plants is accumulated primarily in roots with lesser accumulations in leaves and still less in the other parts of the plant.

Received December 30, 1959

BIBLIOGRAPHY

1. VERNADSKIY, V. I. 1940. Biogeochemical features. Izd. Akad. Nauk SSSR.
2. VINOGRADOV, A. P. 1952. Basic patterns in microelement distribution between plants and environment. In the collection: Mikroelementy v zhizni rasteniy i zhivotnykh (Microelements in plant and animal life). Izd. Akad. Nauk SSSR.
3. KEDROV-ZIKHMAN, O. K. 1958. Co^{60} in studying the role of cobalt as a microelement in plant nutrition. Materialy Mezhdunar. konf. po mirn. isp. atomnoy energii, August 1955, vol. 12.
4. KULIKOV, N. V. Radiocobalt accumulation by phytocoenosis from various depths and soil horizons. Byul. Ural. otd. MOIP. vyp. 3.
5. KULIKOV, N. V. Effect of Na · EDTA on radiocobalt behavior in the soil-plant system. Doklady Akad. Nauk SSSR.
6. PEYVE, YA. V. 1955. Role of microelements in plant and animal nutrition. Izd. Akad. Nauk SSSR.
7. PORYADKOVA, N. A., and S. V. TARCHEVSKAYA. Effect of biocoenosis and runoff on the movement of radio isotopes in soils. Byul. Ural. otd. MOIP. No. 3. (in print).
8. SUKACHEV, V. N. 1947. Principles of the theory of biogeocoenology. Yubil. sb. 30-letiye Velikoy Oktyabr'skoy sotsialisticheskoy revolyutsii, Izd. Akad. Nauk SSSR.
9. TIMOFEYEV-RESOVSKIY, N. V. 1957. Use of radiation and radiators in experimental biogeocoenology. Botan. Zhurnal, No. 2.
10. TITLYANOVA, A. A., and N. A. TIMOFEYEVA. 1959. Mobility of cobalt, strontium, and cesium compounds in soil. Pochvovedeniye, No. 3.
11. SHKOL'NIK, M. YA. 1950. Significance of microelements in plant and animal life. Izd. Akad. Nauk SSSR.
12. HILL, A. C., S. I. TOTH, and F. E. BEAR. 1953. Cobalt status of New Jersey soils and forage. Plants and factors affecting cobalt content of plants. Soil Sci., 76(4).

MANGANESE-IRON CONCRETIONS IN SOILS OF THE SUIFENHO-KHANKA LOWLAND

V. I. ROSLIKOVA, V. L. Komarov Far East Branch, Academy of Sciences, USSR

We know that the formation of manganese-iron concretions (or ortsteins), the study of which is of great importance in resolving problems of soil genesis, is associated with the podzolization or solodization process of soil.

The first to study concretions was Senft (27) who assigned them to the general group of iron ores, but he did not discover how the concretions were formed. Processes contributing to formation of concretions have been examined in studies by the following investigators.

V. V. Dokuchayev considered (9) that the formation of concretions is the result of physicochemical processes taking place in podzolic soils. As a result of soil formation in these soils the iron compounds are leached from the surface horizons and ortsteins are accumulated in the lower-lying horizons. Sibirtsev (22) also saw in the formation of concretions the appearance "... of the podzol formation process," "... in ortsteins, not considering sand and clay, are found all those substances which are extracted from the soils during development of podzol formation processes."

K. D. Glinka (7), and Kravkov (13) associate the presence of orsteins in the podzol with temporary surface excess moisture as the result of which iron compounds together with mobile forms of humus are leached from the upper soil horizons into the deeper horizons; here they undergo complex chemical transformations, taking part in the cementing of these horizons. Vil'yams, (5) who points out that mobile compounds of organic acids (crenic and apocrenic) participate with sesquioxides in the formation of concretions, has expressed a similar point of view.

In Rode's opinion (18) the iron and manganese compounds, as products of colloid decomposition "during periods of soil profile saturation by moisture may be restored, and, then, rising toward the surface and oxidizing, precipitate from the solution...". Popazov (16, 17), as a result of his research, arrives at the conclusion that concretions in the different soil groups were formed at various times under the influence of a single type of soil-formation process which was related to the present-day process being observed in the forest meadow zone. Kovda, Zimovets, and Amchislavskaya (12) associate the formation of concretions in soils of the Zeya-Bureya lowland with a hydrogenic accumulation.

Thus it follows from literary data that there exist different views on concretion formation. This, obviously, is explained by the fact that the concretion formation processes in soils takes place in different ways.

In studying the soils of the Suifenho-Khanka plain — the principal agricultural region of the Primorskiy Kray — we were able to obtain certain data on the characteristics of concretions, which is presented in this article. The problem of the genesis of these new formations in these soils has not been dealt with in literature. The physicochemical properties of soils from which the concretions have been selected, are found in various studies (11, 14, 20, and others). We shall point out only that most soils formed on the Suifenho-Khanka plain are characterized by the presence of a clearly pronounced whitish A_2 horizon with a large quantity of manganese-iron concretions. The presence of this horizon has also been used as the basis for designating these soils as podzolic from the time of the works of Ivanov (10), and Glinka (6).

Recent investigations conducted by the soil laboratory of the Far East Branch, Academy of Sciences, USSR, and the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR, have yielded a wealth of analytical data which has enabled us to reexamine the existing classifications of soils in this vast region and to work out a new soil classification scheme for soils of the Priamur'ye (Amur foreland) and Primor'ye (15).

We studied concretions from the following soils, which were widespread on the Suifenho-Khanka plain: 1) brown-podzolic; 2) meadow-sod podzolized; and 3) meadow soils with signs of solodization. Soil samples were taken by genetic horizons from the following soil profiles, laid out in various areas of the Suifenho-Khanko plain.

Brown-podzolic soils: 1. Profile Number 232. Two kilometers south of the hay mower station (MSS) on the Filino-Iman strip, flat crest of a ridge (low hill) beneath a thicket of oak, hazelnut, and elm. 2. Profile Number 292. On the flat lake-illuvial Sredne-Suifenho plain beneath mixed grasses. 3. Profile Number 105. In the Pozharskiy Rayon, concretions were selected only from the A_2 horizon.

Meadow sod-podzolized soils. 1. Profile Number 26. Primorskaya Experimental Station-city of Ussuriysk, 20-30 year old abandoned land. 2. Profile Number 27. Primorskaya Experimental Station, 10-15 year-old abandoned land.

Meadow soils with signs of solodization. Profile Number 121. Laid out in the Mo River valley, abandoned land beneath a meadow of bentgrass and mixed grasses.[1]

Besides the concretions selected from the foregoing soils, we also studied the tubular iron formations detected by G. I. Ivanov in the outcrops of the Ussuri riverbank at a depth of 2-2.5 meters. Similar formations, but with a less polished surface, were found by A. V. Druzin and G. I. Ivanov on plant roots in the humus horizon of meadow bog soils. Similar formations were first described in 1934 by Ohle (26).

We used the following methods to study concretions. We took a weighed sample of soil of 0.5 kg, washed the concretions from it on sieves, reduced the concretions to an air-dried state, and, by use of an electromagnet, separated them from the soil mass residue, and then selected concretions under a binocular lens. The total content of elements was computed from total analysis data; humus was determined according to the Tyurin method; the mineralogical composition of concretions was determined under a polarizing microscope in transparent sections, polished surfaces, and also in immersion preparations (compounds); the mineralogical composition of the soils was determined under a binocular lens; the quantity of mobile iron in the soils was accounted for by the oxalate extract method.

We shall begin our study of the data obtained with the morphology of concretions and their distribution throughout the soil profile (Fig. 1).

The concretions in these soils are found in 2 forms: 1) spherical, of varying weight and diameter, occurring directly in the soil mass; and 2) in the form of well or slightly cemented tubular formations, occasionally resembling a carrot in outward appearance.

The maximum number of spherical-shaped concretions was concentrated in the A_2 horizon and represents 16%-18% of soil weight (Fig. 2). In the lower-lying horizons this content drops to 0.5% and less. A study of the distribution of concretions in the soil profile by fractions shows that the greatest number of concretions occurs in 3-1 mm diameter particles.

Chemical investigations yielded the following results (Tables 1, 2). We noted a definite pattern in humus distribution from the fractions of various size concretions and from the soil horizons.

The humus content decreases with depth in concretions of all sizes. Thus, in concretions with a diameter > 1 mm, from a meadow soil with signs of solodization (Profile No. 21), the humus content changes throughout the genetic horizons in the following way: In the A_1 horizon the humus content varies between 2.92% and 3%; at a depth of 14-23 cm it is 2.36%, while in concretions from a depth of 23-32 cm humus content is only 0.3%. In the lower horizons in the concretions with the diameter > 1 mm, humus was, generally speaking, not detected. We also observe a relationship between the size of concretions and the humus content in them: the humus content is inversely proportional to the diameter of the concretion (Table 1). For example, in Profile No. 21 (meadow soil with signs of solodization) the concretions in the 0-7 cm layer with a diameter > 1 mm contain 2.92%, while concretions with a diameter < 0.25 mm have 3.52%; in the 7-14 cm layer the concretions > 1 mm have 3% humus, while concretions < 0.25 mm contain 3.85% humus. In the meadow podzolized soil (Profile No. 26) in the A_2 horizon the concretions of 1-0.5 mm contain 1.90% humus, while in concretions > 5 mm no humus was detected. The same picture of change in humus content is observed in the concretions of brown podzolic soil (Profile No. 232).

Table 2 presents the results of a total chemical analysis of concretions: 1) selected from an average sample of all genetic horizons and divided into fractions (Profile No. 26); 2) by fractions and genetic horizons (Profile Nos. 232, 21); and 3) by fractions only from the A_2 horizon (Profile No. 105).

Data on the total chemical composition of concretions points to a high content of SiO_2 (49%-60%), R_2O_3 (29%-43%) as well as MnO, which amounts to 7%-8%. Altogether, the chemical composition of manganese-iron concretions is the same. However, we should point out that their composition changes somewhat with a change in size.

In meadow soils with signs of solodization (Profile No. 21) SiO_2 tends to accumulate in concretions of small size, while Fe_2O_3 noticeably increases with the increase in the size of concretions. The amount of MnO decreases sharply with the decrease in concretion diameter and, in addition, the highest content of MnO is associated with deeper horizons. If in the upper horizons MnO content in fractions > 1 mm in diameter is 3%, MnO content in the lower horizons is 7%. No pattern is detected with respect to the distribution of SiO_2 and Al_2O_3 in brown podzolic soil (Profile No. 232), but iron content increases somewhat with the decrease in the diameter of the concretion. The greatest content of manganese is associated with the concretions of the upper horizons. Tubular iron concretions consist basically of SiO_2 and Fe_2O_3 (Table 2).

A study of the mineral composition of spherical-shaped manganese-iron concretions from fractions > 5 mm diameter in petrographic sections showed that isotropic, diffuse, irregularly

---

[1] Vegetation was described by M.A. Skripka.

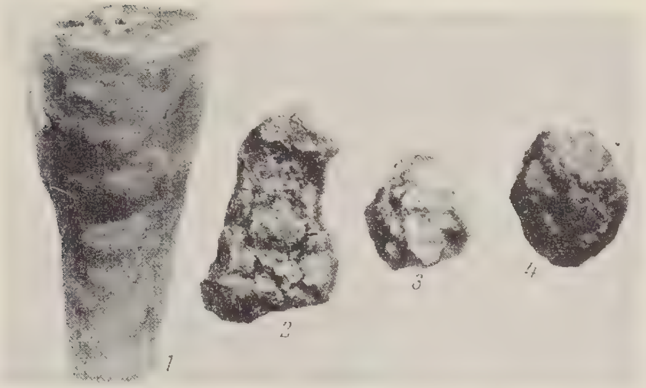


Fig. 1. - Iron-manganese new formations.

1 - tubular iron formations (in outcrops of the Ussuri River at a depth of 2-2.5 m); 2 - tubular formations around plant roots in the humus horizon of meadow bog soils; 3-4 - spherical (globular) manganese-iron concretions deposited directly in the soil mass.

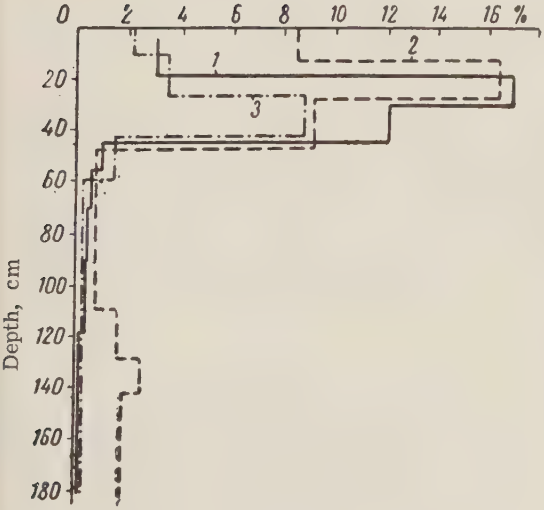


Fig. 2. - Content of manganese-iron concretions in soils of the Suifenho-Khanka lowland.

1 - meadow sod-podzolized (Profile No. 26); 2 - brown podzolic (Profile No. 292); 3 - meadow soil with signs of solodization (Profile No. 21).

shaped accumulations, probably of biological origin, were found at their centers. These formations fill up the pores and cement the quartz grains (from 0.5-0.01 mm in diameter). Besides quartz, we find weathered feldspars from which hydromica scales are developed. All minerals are covered with films of iron and manganese hydroxides. Examination of the polished surfaces of concretions made it possible to prove the existence of psilomelane among the ore minerals.

A study of tubular, hollow concretions has shown that these concretions are characterized by a well-pronounced zonality of component material, which is seen as more ferruginous rings regularly alternating with less ferruginous rings. The most ferruginous ring is formed about the actual root; it includes the finest grains of quartz and biotite, from which is developed chlorite, which decomposes with the precipitation of brown ferric oxides. In addition, we find sericitized grains of feldspar. The less ferruginous rings also consist of quartz, biotite, feldspar, slightly covered with ferric hydroxides. As the concretions develop, the ferruginous rings from the center to the periphery become finer and more broken. It is interesting to note that the ferrugination of the rings is directly related to the decomposition of the terrigenous material. The formation of wider ferruginous rings near the plant root emanates, apparently, from two causes: 1) there is near the root in the solutions an increased concentration of organic acids due to which mineral decomposition and Fe leaching take place. This is confirmed by the fact that the ferruginous rings around the root contain almost twice as much humus as the less ferruginous rings, and 2) around the root the oxygen content has increased as a result of which ferrous iron oxides into ferric oxide and is transformed into a solid phase.

We studied the mineralogical composition of fractions > 0.25 mm in diameter of the soils separated. Data in Table 3 shows that both primary and secondary minerals are characteristic of these fractions. Primary minerals are basically quartz and feldspars; we shall assign to them also the sandy-clay aggregates. The secondary minerals are iron and manganese concretions. Manganese concretions are found chiefly in the lower horizons while the maximum iron concretions are associated with the upper part of the profile. The mineralogical composition of a fraction > 0.25 mm in diameter was studied in immersion preparations (compounds)

Table 1

Humus (after Tyurin) in iron-manganese concretions by fractions

Soil and Profile No.	Depth, cm	Diameter of concretion, m	Humus, %
Meadow soil with signs of solodization, 21	0—7	>1	2,92
		1—0,5	2,97
		0,5—0,25	3,22
		<0,25	3,52
	7—14	>1	3,00
		1—0,5	2,83
		0,5—0,25	3,52
		<0,25	3,83
	14—23	>1	2,36
		1—0,5	2,73
		0,5—0,25	2,91
		<0,25	3,05
	23—32	>1	0,3
	75—85	>1	None
	110—120	>1	"
Brown podzolic soil, 232	0—7	>1	2,21
		1—0,5	1,86
		0,5—0,25	2,34
		<0,25	2,86
	7—12	>1	1,01
		1—0,5	1,08
		0,5—0,25	2,00
		<0,25	2,13
	20—30	>1	0,82
		1—0,5	1,17
		0,5—0,25	1,28
		<0,25	1,43
Brown podzolic soil, 105	15— 25	>1	1,24
		1—0,5	1,31
		0,5—0,25	1,54
		<0,25	1,53
Meadow sod-podzolized soil,26	17— 23	>5	None
		1—0,5	1,96
Brown podzolic soil, 292	29— 27	>1	1,41
		1—0,5	1,98
		0,5—0,25	2,17
		<0,25	2,81
	Tubular concretion		1,1
	"		0,68
	"		1,09

Note: Comma represents decimal point.

after the hydroxide films were removed. Oxalic acid (pH = 3.5) does not remove the hydrooxide film, 10% HCl decomposes the films, as a result of which feldspar and quartz grains, which were buried in the clay substratum, are liberated. Manganese oxide films were removed by sulfuric acid. The mineralogical composition of both ferruginous concretions and manganese concretions is fairly homogeneous and is made up of sandy clay aggregates, quartz, feldspar, micas, chlorites, the percentage of which varies widely among the different horizons. The similarity between mineralogical analyses of soils and concretions indicates that concretions are formed with the assistance of soil minerals (quartz, feldspars, micas). However, these minerals could not be sources of total iron and manganese required for forming such a large number of manganese iron concretions.

For more complete characteristics of the

Table 2

Total analysis of concretions by fractions, in % of ignited matter

Soil and Profile No.	Depth, cm	Concretion diameter, mm	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3+ $+P_2O_5$	CaO	MgO	P_2O_5	MnO	Total
Meadow soil with signs of solodization 21	0—7	>1	53,89	10,82	27,89	38,71	1,15	2,08	0,24	2,68	98,51
		1 —0,5	50,25	9,97	34,68	44,65	0,98	0,86	0,25	2,81	99,55
		0,5—0,25	53,70	12,61	30,19	42,80	0,98	1,67	0,13	0,63	99,78
	7—14	>1	58,27	5,55	28,56	34,11	1,24	1,28	0,15	1,41	97,31
		0,5—0,25	59,64	10,67	24,68	35,35	0,38	0,76	0,14	0,71	96,84
		<0,25	60,90	12,04	22,51	34,55	1,42	Not det'd	0,16	1,05	97,11
	14—23	>1	58,03	7,33	27,72	35,05	0,98	1,37	—	3,48	98,91
		<0,25	66,94	15,27	14,28	29,55	1,12	0,76	0,07	0,53	98,90
	23—32	>1	45,62	5,26	37,54	42,89	1,61	Not det'd	0,22	7,47	97,50
	110—120	>1	54,00	14,80	15,50	30,30	0,84	2,79	0,20	7,93	96,76
Brown podzolic soil, 232	0—7	1 --0,5	56,30	12,33	24,07	36,40	—	—	—	4,06	—
		<0,25	56,28	10,28	26,52	36,80	—	—	—	5,63	—
	7—12	>1	55,28	10,98	21,22	32,20	—	—	—	4,45	—
		<0,25	58,08	11,12	24,88	36,60	—	—	—	1,83	—
	20—30	1 —0,5	56,76	11,27	26,93	38,20	—	—	—	1,83	—
		<0,25	55,10	13,46	27,34	40,80	—	—	—	1,05	—
Brown podzolic soil, 105	15—25	>1	59,50	9,17	22,03	31,20	—	—	—	3,85	—
		0,5—0,25	53,00	13,22	29,78	43,00	—	—	—	1,05	—
	Tubular iron concretion		56,58	7,17	30,36	37,53	0,63	1,12	0,21	0,07	96,93
Brown podzolic soil, 292	22—27	—	53,48	12,99	24,15	42,83	0,76	1,45	0,19	0,18	98,70
Meadow sod-podzolized soil, 26		>5	56,47	7,22	24,09	31,52	0,84	1,78	0,21	8,08	98,65
		5—3	57,97	11,67	18,07	29,89	0,82	—	0,15	6,20	—
		2—1,5	53,80	10,11	29,16	39,48	0,84	1,34	0,21	0,61	96,07
		1—0,5	49,04	8,40	38,94	47,51	0,63	0,88	0,17	1,34	99,40

Note: Comma represents decimal point.

horizons containing concretions, we conducted a determination of the mobile forms of iron. Data (Fig. 3) shows that the highest quantity of mobile iron forms is associated with the upper horizons. Thus, in the brown podzolic soil of Profile No. 232, the iron content at a depth of 130-140 cm equals 4.9 meq, while in the A_1 horizon iron content is 10.6 meq. In the opinion of investigators (4, 19), the Tamm reagent (28) acts chiefly on the complex secondary iron compounds containing organic matter (similar compounds are described in various studies [1, 2, 3, 23]). Since the upper horizons are characterized by the presence of a large quantity of humus, the existence of comparatively large quantities of mobile iron compounds in these horizons is understandable. There are many allusions in literature to the formation of crystallized substances during the aging of sediments which precipitate from the collodial solutions and complex organo-mineral compounds (21, 24, 25). It is quite obvious that the iron forming the mobile organo-mineral complexes precipitates and is subsequently subjected to crystallization (8). Tabulation of the number of manganese iron concretions selected from the different horizons of meadow and brown podzolic soils indicates that the maximum content of concretions is found in the A_2 horizon. At the same time the conditions existing in the A horizon should, it would seem, especially favor the formation of these concretions, i.e.: 1) presence of organic matter; 2) maximum of mobile hydroxides; and 3) evaporation and accumulation processes expressed to the greatest degree. The question arises — how can we explain the association of concretions with the A_2 horizon? In the A_1 horizon, in the presence of humus (6%-12%), the ferric hydroxide for the most part does not precipitate and is leached directly up to the ground waters (1). In addition, during spring droughts, the peptized hydroxides rising upward through the capillaries, dry out, coagulate, often irreversibly. As a result of these processes (partial coagulation, reverse movement) the mobile iron precipitates in the form of concretions only partially in this horizon, equalling 6%-8% of soil weight; the unprecipitated iron continues its complex migration. A periodic excess moisture, associated with a monsoon climate, and poor soil drainage

Table 3

Mineralogical compositions of fractions > 0.25 mm in diameter, as a percentage of the volume

Soil and Profile No.	Depth, cm	Quartz	Feldspar	Iron concretions	Sandy clay aggregates	Manganese concretions	Rock fragments	Carbonates
Brown podzolic soil, 232	0—6	2,4	0,4	41,0	38,0	18,0	0,1	None
	20— 30	8,8	2,2	64,1	0,3	24,8	—	—
	50— 60	13,8	4,6	41,8	30,0	9,7	—	—
	100—110	19,2	3,1	60,2	None	17,6	0,1	—
Brown podzolic soil, 292	0— 12	1,4	0,4	77,7	12,8	7,3	None	—
	22— 27	3,8	0,2	70,0	0,5	26,0	—	—
	50— 60	8,1	0,2	54,5	None	36,1	—	—
	100—110	8,1	0,3	61,2	"	29,4	0,1	—
	160—170	7,1	0,5	54,1	"	38,2	—	—
Meadow soil with signs of solodization 21	0— 7	8,4	2,1	47,4	36,1	6,1	—	—
	14— 23	3,8	2,3	72,7	2,9	18,3	—	—
	23— 39	6,8	3,8	10,5	40,1	38,0	—	23,4
	53— 63	11,8	6.1	23,9	14,7	18,0	—	—
	170—180	16,1	11,7	55,9	None	16,3	—	—
Meadow sod-podzolized soil, 26	0— 7	25,0	35,4	30,5	3,5	5,5	—	—
	17— 23	7,3	3,8	47,8	None	41,1	—	—
	55— 75	36,3	29,1	8,6	1,7	24,2	—	—
	83— 95	29,9	27,2	7,5	4,7	30,7	—	—
	180—190	24,0	27,1	22,6	—	26,2	—	—

Note: Comma represents decimal point.

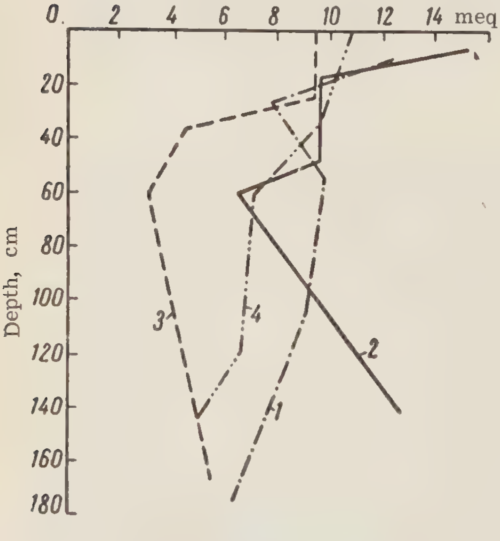


Fig. 3. - Content of mobile iron in meq (after Tamm's oxalate extract method).

1 - brown podzolic soil (Profile No. 292); 2 - meadow sod-podzolized soil (Profile No. 274); 3 - meadow soil with signs of solodization (Profile No. 21); 4 - brown podzolic soil (Profile No. 232).

(beginning with the B_1 horizon the number of particles < 0.001 mm in diameter is 70%-80%), create favorable conditions for restoring Fe^{+++} to Fe^{++}, Fe^{++} penetrates the A_2 horizon quite freely where there is little humus and yet a sufficient amount of oxygen. Here the iron is again oxidized and precipitates as concretions, totalling 16%-18% of soil weight.

Thus, by virtue of the reducing conditions and poor drainage, the iron cannot migrate far beyond the limits of the soil profile, even despite the presence of the podzol formation process, as the result of which we observe the anomalous behavior of iron — the association with upper horizons, with the greatest concentration of iron in the form of concretions in the A_2 horizon.

The concretions are the same in the soil varieties studied: the brown podzolic, meadow, and podzolized and meadow soils with signs of solodization. However, our data (quantitative content in the profile, Fig. 2, chemical composition of concretions of varying size, Table 2) proves that the soils have fairly clear distinctive features with respect to these new formations. Studies are being continued in this direction and we hope that when this research is completed we will be able to define more precisely this complex problem and to draw more accurate conclusions.

Conclusions

1. Manganese-iron concretions in the soils

of the Suifenho-Khanka lowland are associated with the upper A_1 and A_2 horizons, with the maximum in the A_2 horizon. These concretions represent 16%-18% of soil weight.

2. Humus content in these concretions decreases with depth; it is inversely related to the diameter of the concretions.

3. In chemical composition the manganese iron concretions are the same, but with a change in their size the content of the various elements changes in different ways.

4. The similarity between mineralogical analyses of soils and concretions formed in them shows that concretions are formed with the help of terrigenous material to which is added the participation of the substratum. The formation of concretions, obviously, begins from concentration of organo-mineral compounds. The iron moves into them as the result of primary mineral decomposition as well as out of the solutions migrating in the soil. What the primary cause is is not yet clear.

Received June 2, 1960

BIBLIOGRAPHY

1. AARNIO, B. 1915. Precipitation of ferric and aluminum oxides in sandy and rubble (loose rock) soils of Finland. Pochvovedeniye, No. 2 and 83.
2. ALEKSANDROVA, L. N. 1954. Nature and properties of the products of humic acid and humate interaction with sesquioxides. Pochvovedeniye, No. 1.
3. ANTIPOV-KARATAYEV, I. N. 1937. Problem of the movement of iron as organic iron compounds. Trudy konf. po genezisu rud. Izd. Akad Nauk SSSR, Moscow and Leningrad.
4. ANTIPOV-KARATAYEV, I. N., V. V. KELLERMAN, and D. V. KHAN. 1948. Methods for studying the soil aggregate. Izd. Akad. Nauk, SSSR.
5. VIL'YAMS, V. R. 1951. Complete works, Vol. 6.
6. GLINKA, K. D. 1910. Brief resume of Far East Soils. St. Petersburg.
7. GLINKA, K. D. 1931. Soil Science, Moscow.
8. GORBUNOV, N. I. 1954. Mineralogical composition of red earths. Doklady na V Mezhdunar. soveshch. pochvov. Moscow.
9. DOKUCHAYEV, V. V. 1949. Works, Vol. 1.
10. IVANOV, D. V. 1897. Principal characteristics of the oro-geological structure of the Sikhote-Alin' range. Zap. Priamur. otd. Imper. Russk. geograf. obshchestva Vol. 1, No. 3. Khabarovsk.
11. IVANOV, G. I. 1959. Reclamation and utilization of soils of the Prikhankayskaya plain and Ussuri River Valley. Tret'ya sessiya ob''yedin. sovetsko-kitayskogo Uchenogo soveta po probleme r. Amur. Moscow.
12. KOVDA, V. A., B. A. ZIMOVETS, and A. G. AMCHISLAVSKAYA. 1958. Hydrogenic accumulation of silica compounds and sesquioxides in soils of the Amur Foreland. Pochvovedeniye, No. 5.
13. KRAVKOV, S. P. 1937. Soil Science. Leningrad.
14. LIVEROVSKIY, YU. A. and B. P. KOLESNIKOV. 1949. Nature of the southern half of the Soviet Far East. Geografgiz.
15. LIVEROVSKIY, YU. A. and L. P. RUBTSOVA. 1959. Soil classification scheme of plains of the Far East. Pochvovedeniye, No. 4.
16. POPAZOV, D. I. 1957. Certain data on the chemical composition of manganese-iron concretions in sod-podzolic and solodized soils. Doklady TSKHA No. 24.
17. POPAZOV, D. I. 1958. Presence of new formations in the various natural regions as a historical process in a specific soil-formation period. Doklady TSKHA No. 39.
18. RODE, A. A. 1955. Soil Science.
19. RODE, A. A. and I. D. SEDLETSKIY. 1939. Sandy soils of the Kama River terraces. Trudy Pochvennogo instituta im. V. V. Dokuchayeva. Akad. Nauk SSSR. Vol. 19, No. 2.
20. ROSLIKOVA, V. I. 1958. Certain characteristics of meadow soils of the Primor'ye. Pochvovedeniye, No. 5.
21. SEDLETSKIY, I. D. 1945. Colloid-dispersion mineralogy. Izd.-vo Akad. Nauk SSSR.
22. SIBIRTSEV, N. M. 1951. Selected works, Vol. 1.
23. TYULIN, A. F. 1937. Organo-mineral gels in soil, their classification and properties. In the collection: The soil absorbing complex and problems of agriculture. Moscow.
24. FERSMAN, A. YE. 1934. Geochemistry. Vol. 2. Goskhimizdat.
25. CHUKHROV, F. V. 1955. Colloids in the earth's crust. Moscow.
26. OHLE, W. 1934. Enstehbung und Zusammensetzung der Röhrengesteine des Grossen Plöner Sees. Geol. Rundschau 25, No. 4.
27. SENFT, F. 1862. Die Humus. Marsch Torf und Limonit bildungen. Leipzig. 1862.
28. TAMM, O. 1920. Marnstudier i det Nordswenska bursuoqsomridet. Stoch.

SLIGHTLY SALINIZED SOILS OF MICROHILLOCKS AMONG LAKE SOLONCHAKS OF INNER MONGOLIA, CHINESE PEOPLE'S REPUBLIC

B. A. ZIMOVETS, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

In studying salinized soils of the Khulumbuirskiy aymak of Inner Mongolia, we found among the sodium carbonate solonchaks of the ancient drainage basin in the zone of chestnut soils, elevations (hillocks) from which water oozed slightly during the spring and summer. These irregularly rounded elevations have an almost flat crest with a diameter of 2-3 to 5 m, and are 25-35 cm high. They are situated 3-5 to 10 m apart and are found near sodium carbonate lakes, which are observed as beaded systems along the extensive bottom of the drainage basin (hollow). Individual specimens of saltwort (halophytic vegetation) and mulberry trees (Puccenella tenioflora) thrive on the hillocks. We see an association of hillocks along the lake shore which is oriented in the direction of the upper regions of the hollow.

The areas of hillock development represent an unusual hillock-solonchak complex where the sodium carbonate solonchaks containing up to 4% salt are distributed along the depressions and the less salinized sodium carbonate solonchak soils (up to 0.4% salt) along the elevations (hillocks).

We note, on the one hand, in the course of the evolution of hillocks and solonchaks surrounding them, a decrease in salt content (up to 0.1%) in the soils of elevations when the solonchak vegetation, earlier established on these elevations, is replaced by a variety of mixed, meadow grasses ([Agropyrum ramosum], meadow grass [Poa], etc.); on the other hand, an increase in salt content (up to 12%) in the depressions together with a simultaneous change in salt composition from sodium carbonate to sulfate-sodium carbonate. The evolutionary forms of the components in the hillock-solonchak complex are observed to exist 30-50 m from the shore of the lake.

We shall examine the hillock formations of meadow solonchak landscapes, which have not as yet been studied, as soil surface deformation phenomena resulting from frost heaving. We know that soil heaving is a common phenomenon in regions of perennial and seasonal freezing. In addition, the quantity of water in the ground along with the rate of cooling is of the greatest importance. Soil heaving and hillock formation may occur both with or without water inflow from the side (5).

Analyzing the morphological characteristics of the elevations and the conditions of their formation, we arrived at the conclusion that these given forms are unique analogues of northern frozen hillocks, which are ordinarily found in areas of excessive moisture and developed under the influence of water movement toward the freezing front and of hydrostatic pressure during freezing of moisture saturated soils (5). The difference lies in the fact that in this case the hillocks are small and are formed not with the aid of fresh waters but of mineralized waters. Despite the possible inflow of water from the upper regions of the hollow (drainage basin), there is no large development of hillocks here, obviously, because hillocks are formed in southern, warmer latitudes. Perhaps this is associated with the presence of mineralized water; as we know, the water which contains salts, has a lower freezing temperature, which predetermines a small ice accumulation.

According to data in literature (1, 2, 4, 6) and information obtained during our field trips, intensive annual freezing (Table 1) is characteristic of the soils of Inner Mongolia and adjacent areas of Central Mongolia, Southern Zabaykal'ye, and Bol'skoy Khingan. In the meadow plains between mountains, we often detect seats of around-the-year freezing. In this drainage basin we recorded freezing at a depth of 1.9 to 3.2 m in July. From observations by Chinese soil scientists, the seasonally frozen soils in the Gun-khe drainage basin thaw out completely during the following periods: at the middle of July, in the deeply-columnar solonetzes; at the end of July in the columnar solonetzes; and at the end of August in the solonchaks.

Frost heaving of weakly salinized soils, like the heaving of soils in the permafrost region (5, 7), occurs whenever soils are subject to excessive moisture. In this case the ground waters are at a depth of 0.3 to 0.5-0.8 m and, apparently, flow in (tributary) from the upper parts of the hollow, which has brought about the association of heaving hillocks with the shore of the lake oriented toward the upper part of the hollow. From the lake toward the main shore of the hollow the ground waters drop gradually to 2-5 m. Their composition, like the composition of waters flowing out of the

Table 1

Freezing depth of soils in Inner Mongolia, Chinese People's Republic, mm

In the Gun-khe drainage hollow	In the plains between hills in San-khe region
Boring No. 4—2,0—3,0	Boring No. 47—1,6—2,9
Boring No. 5—2,2—3,2	Boring No. 63—2,5—2,7
Boring No. 6—1,9—3,2	Boring No. 69—2,0—3,7
	Boring No. 71—1,9—3,5

Note: Comma represents decimal point.

hillocks, is sodium carbonate, with a total concentration of 2.0-2.5 g/liter; the lake water is mineralized to 4 g/liter (Table 2).

The surface of the ancient drainage basin is flat with small and poorly expressed lake terraces; the surface is generally inclined in the direction of the lower parts. We see a small surface gradient in the drainage basin running from the main shores toward the central part, where the waterlogged and shallow-water Gun-khe River, a tributary of the Khaylar River, passes.

The lake strips are made up of alluvial sand and sandy loam which are covered with clay loam and clay about 2 m thick. Both the upper and lower alluvium layers are weakly salinized (< 1.0%), principally by sodium bicarbonate and sodium carbonate. The soil of the lake depressions is a complex of solonchaks, solonchak-solonetzes, and meadow solonchak soils.

From the shore of the lake towards the terrace banks we note a gradual decrease in the area covered by solonchaks and an increase in the area of solonetzes, chiefly of crusty and shallow-columnar solonetzes. At the shore of the lake depression, where the ground water is at a depth of 5-6 m, we find deeply-columnar solonetzes (Fig. 1).

In August, excavations of a microhillock, out of which the water oozed a month before, revealed that the vertical soil profile is clearly divided into several horizons and resembles the structure of frozen hillocks in the north (5.7). The highest part — 0-20 (15) cm — is dry, gray, clay loam to clay with a blocky, lumpy structure. At a depth of 15(20)-40 cm the layer of clay quicksand, bluish to dark-blue, and saturated by water, with strong traces of the reducing processes, is sharply separated.

Table 2

Chemical composition of waters in the Gun-khe drainage basin, g/liter

Source	Depth, m	Sampling date 1958	pH	Alkalinity		Cl	SO_4	Ca	Mg	Na by difference	Total of ions
				CO_3	HCO_3						
Gun-khe River	from the surface	June 26	8,0	0,012	0,439	0,031	0,004	0,026	0,021	0,125	0,646
Lake	"	"	8,9	0,258	2,043	0,268	0,010	0,018	0,030	1,065	3,434
Ground water beneath deeply-columnar solonetz	5,1	July 1	8,2	0,025	1,159	0,211	0,008	0,041	0,053	0,430	1,902
Ground water beneath shallow-columnar solon.	2,5	"	8,3	0,034	1,363	0,219	0,005	0,013	0,019	0,608	2,227
Ground water beneath solonchak	1,8	"	8,3	0,044	1,496	0,237	0,005	0,009	0,016	0,679	2,441
Water flowing from a frozen hillock	from the surface	June 26	8,9	0,101	1,515	0,045	0,004	0,012	0,007	0,653	2,236

Note: Comma represents decimal point.

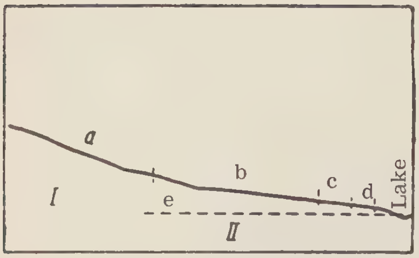


Fig. 1. - Schematic profile of a part of the Gun-khe drainage basin.

a - steppe (chestnut soils); b - solonetzes and meadow-steppe soils; c - sulfate-sodium carbonate solonchaks and old microhillocks; d - sodium carbonate solonchaks and wet microhillocks; e - ground-water level. I - main shore; II - part of drainage basin.

Lower to 180 cm, the soil is characterized by a noticeable decrease in moisture and by an increase in compaction; it is considerably ozidized (ocher-colored).

Soil profile of the microhillock. Soil effervesces with 10% HCl from 18(20) cm.

0-5 cm. Light-gray, dry, clay-clay loam, coarse to blocky, stable structural units, slightly porous, no effervescence. Transition gradual.

5-15 (20) cm. Gray, fresh, clay-clay loam, columnar, stable structural units, solonetz-like. No effervescence. Transition distinct.

15 (20) -40 cm. Grayish to bluish to dark blue, clay, structureless, fluid, water-bearing horizon, effervesces. Transition sharp.

40-80 cm. Gray-dark blue with rusty spots, moist, fine clay loam, compacted, slight crumbling into units resembling cheese particles, effervesces. Transition gradual.

Table 3

Data on analysis of water extracts

Depth, cm	Alkalinity		Cl	SO_4	Ca	Mg	Na by difference	Total of ions
	CO_3	Total in HCO_3						
In % of air-dried soil								
Sodium carbonate solonchak soil on a frozen hillock								
0— 5	0,053	0,202	0,002	0,003	0,002	0,001	0,074	0,284
5— 15	0,037	0,244	0,001	0,005	0,005	0,001	0,087	0,343
20— 30	0,026	0,282	0,003	0,004	0,011	0,001	0,095	0,396
50— 60	0,006	0,149	0,001	0,003	0,006	0,001	0,049	0,209
10—120	0,006	0,107	0,0003	0,003	0,004	0,001	0,035	0,150
Sodium carbonate solonchak in depressions alongside a frozen hillock								
0,0—0,2	0,939	2,812	0,021	0,070	0,055	0,002	1,039	3,999
3—5	0,149	0,478	0,008	0,005	0,009	0,009	0,158	0,667
Meadow weakly solonchak-like soil on an old hillock								
0— 10	None	0,067	0,003	0,004	0,007	0,001	0,020	0,102
17— 27	"	0,076	0,002	0,004	0,006	0,001	0,023	0,112
35— 45	"	0,073	0,002	0,010	0,009	0,001	0,022	0,117
80— 90	"	0,061	0,002	0,002	0,006	0,001	0,017	0,089
Sulfate-sodium carbonate solonchak; alongside an old hillock[a]								
0,0— 0,2	1,600	4,335	0,770	3,079	0,054	0,029	3,565	11,832
0,2— 3,0	0,290	1,013	0,665	1,076	0,043	0,018	1,244	4,059
3— 10	0,073	0,498	0,204	0,005	0,028	0,008	0,275	1,018
15— 25	0,070	0,479	0,139	0,007	0,005	0,004	0,261	0,895
30— 40	0,059	0,434	0,106	0,003	0,006	0,004	0,219	0,772
50— 60	0,073	0,418	0,103	0,003	0,004	0,005	0,211	0,744
80— 90	0,059	0,434	0,106	0,003	0,004	0,004	0,222	0,773
110—120	0,025	0,314	0,075	0,002	0,006	0,004	0,153	0,554
170—180	0,066	0,453	0,102	0,002	0,003	0,003	0,229	0,792
200—210	0,065	0,279	0,019	0,002	0,003	0,004	0,109	0,416

[a] Soil samples were analyzed by Tsuan Tsun-khao.

Note: Comma represents decimal point.

80-180 cm. Rusty-brown, moist, clay, compact, fine-blocky-prism-like, effervesces.

Analysis of water extracts have revealed a comparatively small concentration of salts, principally of sodium carbonate, (0.39%) in the horizons of the hillock. Typical is the salt distribution throughout the profile corresponding to cryogenic water migration conditions (8). In the uppermost 0-5 cm, 5-15 cm layers the salt content is about 0.30%. The maximum salt (0.39%) is associated with the most moist 20-30 cm layer; here we note a relative maximum of chlorides (0.003%). The salt concentration decreases gradually with depth to 0.20%-0.15%. On the surface around the hillock in the 0.20%-0.15%. On the surface around the hillock in the 0-1 cm layer the salt accumulations, likewise basically salts, amount to 4%, dropping sharply to 0.6% at a depth of 3-5 cm (Table 3). As mentioned previously, we find 30-50 m from the lake shore isolated microelevations very similar to size and shape to the hillocks described previously, but differing from them by the presence of a rich, meadow mixed grass vegetation and by the absence of a clay quicksand layer. Meadow weakly-solonchak-like soils with a well-developed humus horizon up to 20 cm thick have been formed on these elevations. Throughout the entire soil profile the salt content is not more than 0.1% (Table 3).

Meadow weakly solonetz-like and weakly solonchak-like soils on an old hillock.

A_1 0-15 cm. Humus, dark gray, fresh, coarse clay loam, indistinct granular, semifriable. Many roots. No effervescence. Transition gradual.

AB 15-28 cm. Brownish to gray, moist, clay loam, granular to nutty, indistinct columnar, compacted; humus tongues along cracks in the frozen stratum of the soil to 70-90 cm, less roots, effervesces from 22 cm. Transition clear.

C_1 28-52 cm. Dark blue to gray, moist, clay loam, fine-nut-like, slightly friable or crumbly, few roots. Transition gradual.

C_2 52-100 cm. Same, only moist with strongly expressed signs of reduction processes.

It appears to us that these are old forms of frozen hillocks (where the cryogenic migration of solutions toward the surface has already ceased, in connection with the general evolution of lake landscapes) directed toward decreasing lake surfaces and lowering ground waters, in the given case to 1.9 m. Solonchaks are also widespread about the old hillocks but have a large quantity of salts (up to 11.8%). The composition of the salt crust is sulfate-sodium carbonate (Table 3); this is proof of the fact that along with salt accumulation there occurs, too, a periodic salt removal (3, 4).

Sulfate-sodium carbonate solonchak. Located alongside an old frozen hillock. Isolated specimens of saltwort (halophytic vegetation), from the surface a saline crust, friable, of a sulfate-carbonate composition, effervesces with HCl throughout the entire profile.

0.0—0.2 cm. Saline crust.

0.2—5.0 cm. Light-gray with brownish tinge, fresh, clay loam, slightly compacted, fine-granular-porous, isolated roots. Transition gradual.

5.0-12 cm. Light-gray, moist, clay loam, fine-granular, fine porous. Transition conspicuous by humus color.

12—30 cm. Lighter than the preceding, moist, variegated with humus tongues (streaks), discolored salt areas, clay loam, almost structureless. Transition gradual.

30-90 cm. Strongly moist, gray-brown, clay loam, cheesy structure, slight horizontal cleavage, humus tongues. Transition apparent by gleying.

90—150 cm. Moist, variegated with dark blue spots and humus tongues, clay loam, prism-like nutty structure (cryogenic).

150-250 cm. Brownish to dark blue, stratified clay loam, clearly horizontally cleavable into slabs, discolored ocherous salt areas (iron admixture). Frozen at a depth of 190 cm.[1]

250-280 cm. Pale yellow (straw-colored), to dark blue, frozen, alluvial-stratified, sandy loam, frequent small black manganese spots.

280-320 cm. Sandy loam-sandy, stratified, frozen.

320 cm. Sandy alluvium, saturated by water.[2]

In conclusion, we should mention that seasonal freezing of soils, heaving and other cryogenic phenomena must be taken into account when we reclaim an area. However, the cyrogenic processes in the subarid zone have been studied only slightly, and the role of seasonal freezing in forming salinized soils has not been defined. As a result, measures to control salts in soils experiencing deep freezing have not as yet been devised.

Under permafrost conditions the cyrogenic migration of water has been artificially controlled by shallow drainage canals which realize active winter accumulation of ice and the subsequent passive removal of runoff water after thawing (8). It is possible that in this way we may also be able to control salt accumulation in the soils, where the cyrogenic migration of salt solutions takes place.

Received June 27, 1960

BIBLIOGRAPHY

1. BESPALOV, N. D. 1951. Soils of the Mongolian People's Republic. Izd. Akad. Nauk.

---

[1] From a boring.

[2] In one hour the water level rose, and was established to be a depth of 190 cm.

SSSR.

2. GORDEYEV, T. P. 1954. Outline of the soils of Northeast China and the eastern part of the autonomous region of Inner Mongolia. Acta Pedologica Sinica, Vol. 2, No. 4.

3. KOVDA, V. A. 1946. Origin and regime of salinized soils. Vol. 1-2. Izd. Akad. Nauk, SSSR.

4. KOVDA, V. A. 1959. Essays on the nature and soils of China. Izd. Akad. Nauk SSSR.

5. (No author given). 1959. Principles of cryopedology (permafrost study). First Part. Izd. Akad. Nauk, SSSR.

6. PRASOLOV, L. I. 1927. Southern Zabaykal'-ye. A soil-geographic outline. Leningrad. Izd. Akad. Nauk, SSSR.

7. SUMGIN, M. I. 1940. A general permafrost study. Moscow and Leningrad.

8. TYUTYUNOV, I. A. 1951. Water movement in peat-gley soil in the freezing period, and frozen state under close-to-surface permafrost conditions. Izd. Akad. Nauk SSSR.

METHODS

EXTRACTION OF FREE (NONSILICATE) IRON AND ALUMINUM FROM SOILS AND CLAYS

I. G. TSYURUPA, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

In spite of the existence of many methods (17-29) of extracting free iron oxides[1] from soils and clays (Table 1) and their extensive use in various types of investigations, 3 questions remain unsolved: 1) how comparable these methods are (i. e., how close are the amounts of iron extracted by the various methods from one and the same sample); 2) how fully free iron is being separated; and 3) how strongly silicate iron, which forms part of the crystal lattice of alumino- and ferrisilicates, is held.

The objectives of the present article are: a) to compare the amounts of iron and aluminum extracted by the Tamm, Stefanovits, and Deb methods from various samples containing iron and aluminum, and b) to determine what forms of Fe and Al are extracted by the reagents used in these methods (i. e., how they meet the requirement of extracting only free Fe oxide and not silicate iron).

We investigated artificial and natural compounds of the iron oxide and hydroxide group ($Fe(OH)_3$ of various ages and methods of preparation, hydrogoethite, hydrohematite, and hematite) and various iron-containing clays and minerals of the silicate group (bentonite and kaolin clays, nontronite, ferrihalloysite, muscovite, biotite, and microcline).

The samples under study were triturated in a porcelain mortar and passed through a sieve with openings 0.25 mm in diameter. Then the air-dry samples were treated with the Tamm, Stefanovits, and Deb solutions.

The Tamm method (27, 28) has been used for a long time in soil science and does not require special description.

The Deb method (19) was proposed in 1950 on the basis of the method of Galabutskaya and Govorova (7) for bleaching kaolin, and is being used by foreign authors primarily for removing free Fe oxides from soils and clays when preparing them for X-ray analysis. According to the Deb method 0.25-1 g of soil or clay is treated with a 4% solution of Na hydrosulfite for 30 min at 40-45°C and then with 0.02 N HCl for 15 min at room temperature. During treatment the iron is reduced and changes into an easily soluble state. In our work we used the Deb method as modified by A. G. Amchislavskaya, who suggested filtering the suspension instead of centrifuging it, and determining the extracted iron (after its oxidation with ammonium persulfate) trilonometrically.

The Stefanovits method (26) was proposed in 1955. It is based on obtaining internally complex compounds (chelates) of metallic soil ions with the complex (chelatizer) forming part of the extracting reagent — a 0.1 N solution of trilon B in a 1 N solution of KCl. According to the Stefanovits method 5 g of soil are boiled for 3 min with 50 ml of the reagent. Then the extract is filtered and the extracted Fe and Al are determined by titration with a 0.1 N solution of $ZnCl_2$ in the presence of a number of indicators. Titration is achieved by the direct and reverse methods at definite pH and temperature conditions. The necessity of strictly fulfilling the titration conditions and of preparing fresh indicators daily make the method difficult to use for mass determinations. Therefore we modified the Stefanovits method: we used the extracting reagent and the method of extracting strictly according to the specifications of the author, but then we destroyed the chelate formed by oxidation and ignition at 450-500°C and determined the Fe and Al by the usual colorimetric and volumetric methods.

Data on the extraction of iron and aluminum from the soil samples investigated are given in Tables 2-7.

Table 2 shows that: 1) the Tamm, Stefanovits, and Deb method extract different amounts of Fe from free iron compounds. Tamm's[2] reagent was the most active in the majority of cases.

2) Neither of the methods extracts the entire iron contained in the sample studied. Less than

---

[1] The term "free iron oxides" was introduced by American authors to mean all the natural amorphous and crystalline compounds of Fe with oxygen and the hydroxyl ion.

[2] This is possibly determined by the pH of the reagents used (Table 1).

Table 1

Existing methods of extracting free iron from soils and clays

Author of the method	Extracting reagent	pH	Method of extraction	Notes
Tamm (27, 28)	Oxalate buffer	3.2-3.3 (3.9)	Twofold treatment of soil with the oxalate buffer for 30 min at room temperature	
Drozdov[a] (21)	H_2S	Weakly alkaline	Passing a stream of H_2S through the soil suspension at 80°C for 30 min. The sulfides formed are dissolved after H_2O_2 and H_2SO_4 are added	With large amounts of Fe treatment is repeated 2-3 times
Drozdov and Truog (22, 23)	H_2S	Same	Same. The sulfides formed are dissolved in 0.05 N HCl at 80-90°C	Same
Truog and others (29)	H_2S (as a result of the interaction of oxalic acid and Na_2S)	–	–	–
Jeffries (24)	H_2 (as a result of the interaction of oxalic acid and metallic Al)	–	Boiling the soil suspension with oxalic acid and an aluminum rod for 20 min.; addition of H_2O_2 HCl and further boiling for 5 min to dissolve the sulfides	With large amounts of Fe, treatment is repeated 2-3 times
Allison and Scarseth (18)	Sugar solution	–	Anaerobic reduction of iron compounds (to convert Fe into an easily soluble form)	–
Dion (20)	H_2 (as a result of the integration of Na tartrate and metallic Al)	–	Heating of the soil with water at 40°C for 20 min, with Na tartrate and an aluminum rod for 15 min and with 0.05 N HCl for 3 min (for dissolving the sulfides formed)	With large amounts of Fe the treatment is repeated
Deb (19)	4%-5% solution of $Na_2S_2O_4$	2.9-3.5	Heating the soil suspension with an $Na_2S_2O_4$ solution for 30 min at 40-45°C; then with 0.02 N for 5 min at room temperature (to dissolve the sulfides)	Same
Aguilera, and Jackson (17)	$Na_2S_2O_4$	7.3	Heating the soil sample with a 0.3 M solution of sodium citrate (or with the addition of trilon B) at 90°C for 5 min and with 1 g of $Na_2S_2O_4$ for 10 min	"
Mitchell and Mackenzie (25)	4% solution of $Na_2S_2O_4$ in a 0.3% solution of NaOH	5.8-6.0	Twofold treatment of the soil suspension with an $Na_2S_2O_4$ solution at 40-50°C for 15 min (with intermediate and final treatment of the sample with 0.05 N HCl for 3 min at room temperature)	"
Stefanovits (26)		4.0-4.2	Boiling the soil with the reagent for 3 min, filtration, and 5-fold washing of the sample in a funnel with 1 N KCl	–

[a] There is a modification of this method by Firsova (16).

half of the iron is extracted even from freshly precipitated amorphous $Fe(OH)_3$.

3) The amount of Fe extracted by the Tamm and Stefanovits methods decreases noticeably as the degree of crystallization of the compounds of the iron oxide and hydroxide group increases.

The opposite is true of the Deb method. Thus, 37.7% and 17.8% of the total content of Fe_2O_3 are extracted by the Tamm and Stefanovits

Table 2

Comparative data on the extraction of iron from various compounds of the Fe oxide and hydroxide group (average from 2-3 determinations)

Samples investigated	Fe_2O_3 extracted					
	mg/100 g of sample			% of total content		
	Tamm	Stefanovits	Deb	Tamm	Stefanovits	Deb
Freshly prepared Fe $(OH)_3$, dried at 18°C	33 241	15 751	2 050	37,7	17,8	2,3
Same, at 140°C	21 259	15 460	Not det'd.	22,1	16,0	—
7-year old $Fe(OH)_3$, dried at 18°C	3 15558	13 045	1640	36,6	15,1	1,9
Same, at 150°C	26 586	Not det'd.		27,6	—	—
Commercial $Fe(OH)_3$	8 168	4 832	2 460	8,4	5,0	2,6
Hydrogoethite, Urals, Bakal	3 080	3 480	7 175	3,2	3,6	7,5
Hydrohematite with an admixture of geothite, Azerbaydzhan	6 677	1 933	6 765	6,7	2,5	6,9
Hematite, Ukrainian SSR, Krivoy Rog	60	305	3 280	0,06	0,3	3,2

Note: Comma represents decimal point.

Table 3

Comparative data on the extraction of iron and aluminum from various clays and mineral-alumosilicates (average of 2 determinations)

Samples investigated	Extracted Fe_2O_3						Extracted Al_2O_3					
	mg/100 g of sample			% of total content			mg/100 g of sample			% of total content		
	Tamm	Stefanovits	Deb	Tamm	Stefanovits	Deb	Tamm	Stefanovits	Deb	Tamm	Stefanovits	Deb
Bentonite clay, Oglanlin deposit	45	61	118	3,3	4,5	8,6	232	23	28	1,7	0,17	0,20
Nontronite, Northern Kazakhstan	252	390	Not det'd.	4,8	7,4	—	42	27	Not det'd.	0,1	0,07	—
Kaolin clay, Prosyanov deposit	12	23	342	1,8	3,5	51,8	15	92	28	0,04	0,24	0,08
Kaolin clay, Mariupol' deposit	8	22	240	1,5	4,1	45,3	12	81	33	0,03	0,25	0,10
Ferrihalloysite, Anatoliya deposit	874	690	Not det'd	4,0	3,2	—	351	250	Not det'd	2,8	2,0	—
Muscovite, Irkutsk Oblast', Mam deposit	393	91	205	16,7	3,8	8,7	463	232	172	1,3	0,67	0,50
Biotite, Urals, Vishnevyye mountains	7475	2409	2633	38,3	12,3	13,5	3050	305	67	14,3	1,43	0,31
Microcline, Karelo-Finnish ASSR, Chupa	228	218	302	50,6	48,4	64,3	54	21	72	0,25	0,10	0,34

Note: Comma represents decimal point.

method, from freshly prepared, amorphous $Fe(OH)_3$ (typical example of the free and mobile form of iron), 3.2% and 3.6% of the Fe_2O_3 are extracted from partly crystallized hydrogoethite, and 0.06% and 3.5% of the Fe_2O_3 are extracted from fully crystallized hematite (typical example

Table 4

Extraction of Fe from compounds of the iron oxide and hydroxide group with various methods of treatment (average from 2-3 determinations)

Samples investigated	Method of treatment		Fe_2O_3 extracted					
			mg/100 g of sample			% of total content		
			Tamm	Stefanovits	Deb	Tamm	Stefanovits	Deb
Freshly prepared $Fe(OH)_3$	3-fold extraction	First	33 241	14979	2 050	37,7	16,9	2,3
		Second	15 461	11214	11 070	17,5	12,7	12,5
		Third	4 638	10951	4 674	5,3	12,4	5,4
		Total	53 340	37144	17 794	60,5	42,0	20,2
Same, heated at 140°C	Same	First	21 259	15560	Not det'd.	22,1	16,0	—
		Second	19 326	11309	"	20,1	11,7	—
		Third	12 369	12292	"	12,9	12,7	—
		Total	52 954	39062	Not det'd.	55,2	40,4	—
7-year old $Fe(OH)_3$	Same	First	31 558	13 045	1 640	36,6	15,1	1,9
		Second	20 929	12 852	5 166	24,3	14,9	6,0
		Third	14 119	14 688	6 888	16,4	17,5	8,0
		Total	66 606	40 585	13 694	77,3	47,5	15,9
Commercial Fe $(OH)_3$	Double amount of reagent		Not det'd.	6 571	Not det'd.	—	6,8	—
	Triple time of integration		Not det'd.	7 924	Not det'd.	—	8,2	—
	3-fold extraction	First	8 169	4 875	2 460	8,4	5,6	2,6
		Second	5 813	3 682	4 674	6,0	3,8	4,8
		Third	1 561	3 865	7 624	1,6	3,7	7,9
		Total	15 443	12 422	14 758	16,0	13,1	15,3
Hydrohematite, Azerbaydzhan	Double amount of reagent		Not det'd.	2076	Not det'd.	—	2,1	—
	Triple time of interaction		Not det'd.	2492	Not det'd.	—	2,5	—
	3-fold extraction	First	6 677	1 933	6 765	6,7	1,9	6,8
		Second	5 315	1 773	11 808	5,4	1,7	12,0
		Third	1 993	1 163	8 856	2,0	1,1	9,0
		Total	13 985	4 869	27 429	14,1	4,7	27,8
Hematite, Ukrainian SSR, Krivey Rog	Double amount of reagent		Not det'd.	296	Not det'd.	—	0,2	—
	Triple time of interaction		Not det'd.	305	Not det'd.	—	0,3	—
	3-fold extraction	First	60	305	3 485	0,06	0,3	3,4
		Second	30	131	4 920	0,03	0,13	4,9
		Third	Traces	147	7 503	—	0,14	7,5
		Total	90	583	15 908	0,09	0,6	15,8

Note: Comma represents decimal point.

Table 5

Extraction of Fe and Al from clays and aluminosilicate minerals with various methods of treatment (average of 2 determinations)

Sample investigated	Method of treatment		Fe_2O_3 extracted						Al_2O_3 extracted					
			mg/100 g of sample			% of total content			mg/100 g of sample			% of total content		
			Tamm	Stefanovits	Deb	Tamm	Stefanovits	Deb	Tamm	Stefanovits	Deb	Tamm	Stefanovits	Deb
Bentonite clay, Oglanlin deposit	3-fold extraction	First	40	50	114	3,0	3,6	8,3	232	23	28	1,70	0,17	0,20
		Second	14	18	54	1,0	1,2	4,0	7	15	108	0,05	0,11	0,71
		Third	8	12	136	0,6	0,9	10,0	None	38	92	0	0,27	0,67
		Total	62	80	304	4,6	5,7	22,3	239	106	228	1,75	0,55	1,58
Nontronite, Northern Kazakhstan	Same	First	252	390	Not detd.	4,8	7,4	—	42	27	Not detd.	0,1	0,07	—
		Second	27	16	"	0,5	0,3	—	Trace	0	"	Trace	0	—
		Third	1	12	"	0,02	0,2	—	"	0	"	Trace	0	—
		Total	280	418	Not detd.	5,3	7,9	—	42	27		0,1	0,07	—
Kaolin clay, Prosyanov deposit	Same	First	12	23	342	1,8	3,5	51,8	15	92	28	0,04	0,24	0,08
		Second	4	11	68	0,6	1,6	10,3	4	9	23	0,01	0,02	0,07
		Third	6	8	22	0,8	1,2	3,4	2	0	Trace		0	0
		Total	22	42	512	3,2	6,3	65,5	21	101	51	0,05	0,26	0,15
Kaolin clay, Mariupol' deposit	Same	First	8	22	240	1,5	4,1	45,3	12	81	33	0,04	0,25	0,11
		Second	7	10	136	1,3	1,9	25,6	12	13	Trace	0,04	0,04	Trace
		Third	5	9	68	0,9	1,7	12,8	15	Trace		0,05	Trace	—
		Total	20	41	444	3,7	7,7	83,7	39	94	33	0,13	0,29	0,11

Table 5 Continued

Sample investigated	Method of treatment		Fe_2O_3 extracted						Al_2O_3 extracted					
			mg/100 g of sample			% of total content			mg/100 g of sample			% of total content		
			Tamm	Stefanovits	Deb	Tamm	Stefanovits	Deb	Tamm	Stafanovits	Deb	Tamm	Stefanovits	Deb
Ferrihalloysite, Anatoliya deposit	Same	First	874	690	Not det'd.	4,0	3,2	—	351	25	Not det'd.	2,8	0,2	—
		Second	874	690	"	4,0	3,2	—	176	12	"	1,4	0,1	—
		Third	874	1240	"	4,0	5,7	—	49	5	"	0,4	0,04	—
		Total	2622	2620	"	12,0	12,1	—	576	42	—	4,6	0,34	—
Muscovite, Irkutsk Oblast', Mam deposit	"	First	393	91	205	16,7	3,8	8,7	463	232	167	1,3	0,67	0,50
		Second	33	34	136	1,4	1,4	5,8	247	7	42	0,72	0,02	0,12
		Third	0	24	102	0	1,0	4,3	27	45	49	0,07	0,13	0,14
		Total	426	159	443	18,1	6,2	18,8	737	284	258	2,1	0,82	0,76
Biotite, Urals, Vishnenyye Mountains	"	First	7475	2409	2633	38,3	12,3	13,5	3050	305	47	14,3	1,43	0,22
		Second	1063	2492	1200	5,4	12,7	6,3	400	175	77	1,9	0,82	0,36
		Third	664	1412	716	3,4	7,2	3,6	17	61	32	0,08	0,28	0,17
		Total	9202	6306	4549	47,1	32,2	23,4	3467	541	156	16,3	2,53	0,75
Microcline, Karele-Finnish ASSR, Chupa River	"	First	237	233	302	52,7	51,8	4,3	84	21	72	0,37	0,10	0,34
		Second	6	18	82	1,3	4,0	5,2	3	Traces	82	0,01	Traces	0,36
		Third	5	10	102	1,2	2,2	0,7	11	32	102	0,06	0,14	0,46
		Total	248	261	486	55,2	58,0	100,2	98	53	256	0,44	0,24	1,16

Note: Comma represents decimal point.

Table 6

Results of experiments on the extraction of Fe and Al by the Deb method from equivalent samples of various artificial preparations and natural minerals

Samples investigated	Total Fe_2O_3 content, %	Sample taken, g	Fe_2O_3 content in sample, mg	Fe_2O_3 extracted		Al_2O_3 extracted	
				mg	% of total	mg	% of total
Freshly prepared $Fe(OH)_3$	88,15	0,56	500	272	54,5	—	—
7-year old $Fe(OH)_3$	86,10	0,58	500	264	52,8	—	—
Commercial $Fe(OH)_3$	96,35	0,52	500	278	55,6	—	—
Hydrogoethite	96,35	0,52	500	184	36,7	—	—
Hydrohematite	98,40	0,51	500	182	36,5	—	—
Hematite	100	0,50	500	86	17,2	—	—
Oglanlin bentonite	1,36	37	500	72	14,5	120	0,87
Prosyanov kaolin	0,66	60	500	305	61,0	60	0,15
Muscovite	2,35	21	500	76	15,3	154	0,45
Biotite	19,49	2,5	500	117	23,2	240	1,1
Microcline	0,47	107	500	254	50,8	68	0,3

Note: Comma represents decimal point.

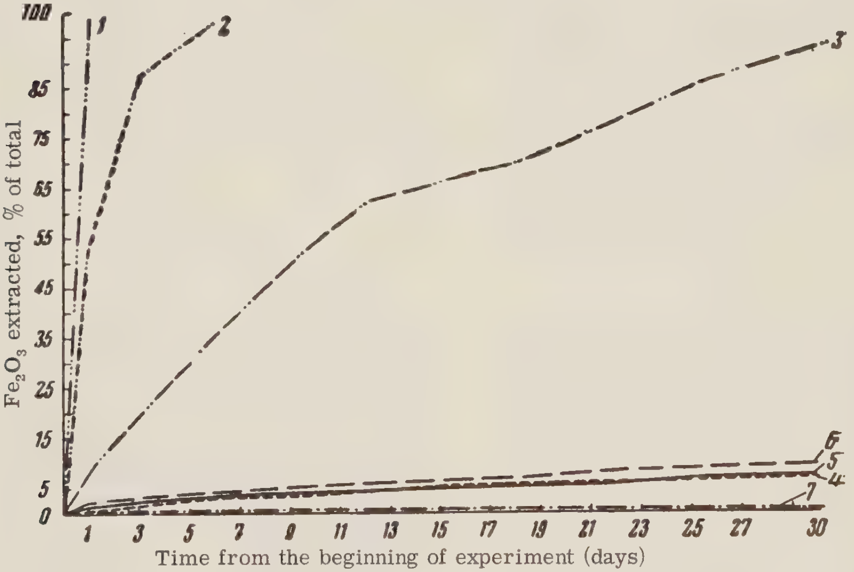


Fig. 1. - Iron extraction from artificial and natural non-silicate Fe compounds with a 1 N H_2SO_4.

1 - Fe humate; 2 - freshly precipitated $Fe(OH)_3$; 3 - Commercial $Fe(OH)_3$; 4 - hydrogoethite; 5 - limonite; 6 - hydrochematite; 7 - hematite.

of the free form of iron, insoluble under normal conditions). Using the Deb method 2.3%, 7.5%, and 3.5% of the total iron are extracted, respectively, from these samples.

After amorphous $Fe(OH)_3$ is heated at 140-150°C, i. e., after dehydration and partial crystallization, the extraction of iron by the Tamm and Stefanovits reagents decreases noticeably.

Table 3 shows that: 1. A considerable amount

Table 7

Results of the treatment of various minerals and soils with 1 N H_2SO_4 until the full cessation of iron separation

Samples investigated	Genetic horizons	Amount of iron extracted in % of its total content
Freshly prepared, amorphous $Fe(OH)_3$	—	100,0
Commercial $Fe(OH)_3$	—	63,7
Limonite, Urals, Khalilove	—	4,9
Hydrogoethite, Urals, Bakal	—	2,1
Hydrohematite with an admixture of goethite, Azerbaydzhan	—	6,0
Hematite, Ukrainian SSR, Krivoy Rog	—	Traces
Ferrihalloysite, Anatoliya deposit	—	44,8
Nontronite, Saysk deposit	—	65,8
Biotite, Urals, Vishnevyye Mountains	—	100,0
Various podzolic soils, Karelia, Profiles 58, 132, and 538, A. A. Marchenko	A_2 A_2 A_2	72,6 100,0 92,3
Moderately podzolic sod soil, Yaroslav Oblast', Profile 8, M. M. Abramova	A_1 A_2 B_2 C	66,8 64,9 62,5 75,1
Thick chernozem, Kursk reservation, Profile 2, Ye. A. Afanas'yeva	A C	49,6 84,0
Red earth, Chakva, Profile 23, S. N. Starykh	A C	49,3 44,8

Note: Comma represents decimal point.

of iron is extracted by means of the methods studied from various aluminosilicates.

2. Less aluminum is extracted than iron (even though the total Al content in the samples investigated is several times higher than the Fe content).

3. Iron is most energetically extracted by the Deb method, and aluminum, by the Tamm method.

A comparison of the data in Tables 2 and 3 shows that the intensity of iron separation from silicates is the same as from free Fe compounds. However, it must be emphasized that the separation of iron from its free compounds and from silicates is of a basically different nature. Fe hydroxides are amorphous, as a rule (5), and dissolve in the same manner as simple salts. The lattice of crystalline, free iron oxides consists of oxygen and iron ions (usually with insignificant admixtures of other elements), alternating in a definite order. In hematite, the extreme member of this series, each Fe^{+++} is surrounded by 6 O^{--}, while each O^{--} is surrounded by 4 Fe^{+++} (5). In such a lattice all iron ions have the same energy and their extraction is actually analogous to the dissolution of salts.

The structure of silicates and aluminosilicates is considerably more complicated. The main structural unit of silicates consists of oxygen silicate tetrahedra $[SiO_4]^{----}$, bound in various combinations by their angles (5). The Si^{++++} in these tetrahedra may be isomorphously replaced by Al^{+++} and Fe^{+++}. Therefore, aluminum and iron in silicates are either surrounded by four O^{--}, or may occur in the form of individual ions, neutralizing the charge of the anion layer.

In the majority of clay minerals — aluminosilicates, the main member of the crystal lattice are oxygen silicate tetrahedra and aluminosilicate octahedra (9). In kaolin minerals the charges of each structural element are equilibrated, while the isomorphous replacement of Al^{+++} by Fe^{+++} and other elements is very weak. Isomorphous replacements of the Si^{++++} of tetrahedral layers by Al^{+++}, and of the Al^{+++} of octahedral layers by Mg^{++}, Fe^{+++}, and other elements are widespread in montmorillonite minerals. The aluminum of the tetrahedral layer cannot be replaced by iron or another cation, while the aluminum of the octahedral layer may be fully substituted. Isomorphic replacement unbalances the lattice of montmorillonite minerals and increases their exchange capacity.

Because of such a lattice structure of silicates and aluminosilicates, part of the aluminum ions are strongly bound, whereas iron ions are bound less strongly and separated more easily under the influence of various reagents. The process of Fe^{+++} and especially Al^{+++} separation from these minerals as such is governed by crystall-chemical laws and has no analogy with the process of dissolution.

The data in Tables 2 and 3 show that the Tamm, Stefanovits, and Deb reagents only partially dissolve free iron oxides (even amorphous products), but at the same time extract Fe and Al which form part of the crystal lattice of silicates. The fact that clay minerals are partially decomposed when free iron oxides are removed from soils and clays is mentioned in the work of Deb (19), Mitchell and MacKenzie (25), and Dion (20), but these authors did not determine the intensity of the process of decomposition. Silicates are most strongly decomposed by the Tamm reagent; a noticeable amount of SiO_2 from them enters the Tamm extract. An especially large amount of silic acid separates from muscovite, up to 8.6% of its total content in this mineral.

The data obtained prompted us to repeat the extraction of iron and aluminum from the samples studied under a more rigid treatment with the Tamm, Stefanovits, and Deb reagents. The results of these experiments are given in Tables 4 and 5. They allow the following conclusions to be made:

1. By increasing the amount of the reagent or the time of its interaction with the samples studied (especially with compounds of the Fe oxide and hydroxide group), considerably more iron is separated than on treatment strictly according to the Tamm, Stefanovits, and Deb methods. The three successive treatments of one and the same sample is even more effective (using in each treatment the amount or reagent and time recommended by these authors). However, a more rigid treatment does not lead to the full separation of iron. Thus, the maximum amount of Fe separated by the three successive treatments with the Tamm, Stefanovits, and Deb reagents reaches 77%, 47%, and 20% for weakly crystallized $Fe(OH)_3$; 14%, 4%, and 27% for hydrohematite; and 0.1%, 0.6% and 16% for hematite.

2. The maximum amount of iron is extracted during the interaction of Fe oxide and hydroxide compounds with the Tamm reagent in the first treatment; later the separation of iron gradually decreases. During the interaction of the same samples with the Deb reagent (and partly the Stefanovits reagent) more iron separates after the second and even the third treatment. Apparently the Tamm reagent acts more rapidly and more energetically than the Stefanovits and Deb reagents. The latter is especially slow and dissolves free iron (and even amorphous hydroxide).

It is interesting to note the close amounts of iron (15%, 20%, and 27% of its total content) separated from all artificial and natural free Fe compounds investigated after a threefold treatment with the Deb reagent. The degree of crystallization of free iron has little effect on its solubility in the Deb reagent, while in the case of the Tamm and Stefanovits reagents, crystallization plays the decisive role.

3. The separation of iron from kaolin clays, nontronite, and microcline ceases during the first treatment. The extraction of Fe from bentonite clay, ferrihaloysite, and micas is very prolonged and repeated treatments yield a considerable additional amount of iron.

The separation of aluminum from nontronite and kaolin clays also practically ceases during the first treatment. Repeated treatments yield noticeable and sometimes even increasing amounts of Al from the other silicates. The increase of the intensity of aluminum separation during repeated treatments points, apparently, to the "loosening" and gradual composition of the crystal lattice of the minerals.

Table 6 shows the results of the extraction by the Deb method of Fe and Al from samples containing the same amounts of iron (500 mg Fe_2O_3). These data fully confirm the results of the preceding experiments and show that iron separates with the same intensity both from silicates and from free iron compounds.

Thus 52%-55% of the total amount of iron separated from $Fe(OH)_3$ and 51% and 61% from microcline and kaolin clay. The amount of iron extracted from hematite was 17.2% and from bentonite clay and muscovite, 14% and 15% respectively.

Thus we found no basic difference between the action of the Deb reagent on free iron compounds and silicates.

From 1952-1954 the author of the present article studied the influence of the degree of crystallization of various artificial and natural iron compounds on their solubility (15). As solvent he used 1 N sulfuric acid. The main results of this investigation are given in Table 7 and in Figure 1.

The data show that 1 N sulfuric acid practically does not decompose the natural minerals of the iron oxide and hydroxide group, but extracts Fe well from soils (apparently from secondary formations of a type such as described by Aarnio [1], Antipov-Karatayev [3], Tyulin [12-14], Ponomereva [10], Aleksandrova [2], and other authors) and from clay minerals with a layered type of structure. A decrease in the concentration of H_2SO_4 (and HCl) solutions sharply reduces their effectiveness, even in the case of artificial amorphous $Fe(OH)_3$. The method used by us to obtain sulfuric acid extracts is very simple: the sample investigated (1-20 g, depending on the nature and composition of the sample analyzed) is washed in funnels with a 1 N solution of H_2SO_4 until there is no reaction to iron in the filtrate. Then aliquot parts of the extract are taken and Fe^{++} and Fe^{+++} are determined in them by the usual colorimetric or volumetric methods.

Conclusions

1. The methods of Tamm, Stefanovits, and Deb are not equal in their action; different amounts of iron and aluminum are extracted by them from one and the same sample.

2. The reagents used in these methods only partly dissolve free iron (even amorphous forms), but at the same time they separate considerable amounts of silicate Fe. The intensity of iron separation from the samples of free Fe and silicates investigated is practically the same.

3. Aluminum separates less easily from silicates than iron, a fact which is easily explained by the structure of the crystal lattice of these minerals and the unequivalent position of Al^{+++} and Fe^{+++} in it.

4. The Tamm reagent separates Fe intensively from amorphous or weakly crystalized free iron compounds and Al from silicates, but hardly affects well-crystallized forms of free iron. The Deb method has practically the same effect on amorphous and crystalline compounds of the Fe oxide and hydroxide group and extracts iron energetically from the soil, but hardly affects Al. The Stefanovits method occupies an intermediate position between the Tamm and Deb methods (it is closer to the Tamm method).

5. Because of the selective action of the Tamm, Stefanovits, and Deb reagents on various groups of free iron compounds, these methods should be differentially used for various soils (i. e., the method of extracting Fe from a given soil must be selected taking into account the characteristics of its chemical and mineralogical composition).

It is best to use the Tamm reagent, which acts intensively precisely on amorphous and weakly crystalline Fe compounds, for soil rich in amorphous and easily available compounds (bog, gleyed, and podzolized soils). The Deb reagent, which dissolves amorphous as well as crystalline Fe oxides equally well, is better suited for soils rich in well-crystallized free iron compounds (red earths, and laterites).

6. To separate the amorphous and silicate forms of soil iron from free crystalline (non-silicate) Fe it is best to use extracts made with a 1 N solution of sulfuric acid.

7. It is imperative that studies be continued on the forms of Fe and Al in soils and methods of extraction with reagents of various types:

a) capable of extracting the total amount of mobile forms of iron and aluminum (without separation into non-silicate and silicate forms), and b) capable of reliably separating free (non-silicate) and silicate forms of sesquioxides and determining the content of each of these forms. The most promising reagents for the foregoing purposes are, apparently, chelators with various energies of chelation.

Received July 7, 1960

BIBLIOGRAPHY

1. AARNIO, V. O. 1915. Precipitation of iron and aluminum oxides in sandy and gravelly soils of Finland. Pochvovedeniye, No. 2-3.

2. ALEKSANDROVA, L. N. 1954. Nature and properties of the products of the interaction of humic acids and humates with sesquioxides. Pochvovedeniye, No. 1.

3. ANTIPOV-KARATAYEV, I. N. 1937. Problem of the migration of iron in the form of its organic compounds. Trudy Kenferentsii po genesisy rud. Izd. Akad. Nauk SSSR.

4. ANTIPOV-KARATAYEV, I. N., V. V. KELLERMAN, and D. V. KHAN. 1948. The soil aggregate and its methods of investigation. Izd. Akad. Nauk SSSR.

5. BETEKHTIN, A. G. 1950. Mineralogy. Izd. Akad. Nauk SSSR.

6. VERIGINA, K. V. 1953. Characterization of the processes of soil gleization. Trudy Pochvennogo instituta Akad. Nauk SSSR. Vol. 41.

7. GALABUTSKAYA, YE. and R. GOVOROVA. 1934. Bleaching of kaolin. Mineral. syr'ye. No. 4.

8. GANTIMUROV, I. I. 1937. Method of determining ferrous and ferric iron in soils irrigated with runoff-water. Zh. Priklad. khimii. 10(8).

9. GRIM, R. E. 1956. Mineralogy of clays. IL, Moscow.

10. PONOMAREVA, V. V. 1949. Reactions during the interaction between crenic and apocrinic acids. Pochvovedeniye, No. 11.

11. RODE, A. A. and I. D. SEDLETSKIY. 1939. Sandy soils of the terraces of the Kama River. Trudy Pochvennogo instituta Akad. Nauk SSSR. 19(2).

12. TYULIN, A. F. 1937. Organo-mineral gels in the soil, their classification and properties. In the collection: Soil adsorption complex and agricultural problems. Moscow.

13. TYULIN, A. F. 1938. Forms of the bond between humic substances and the mineral portion of soil colloids and their importance for the understanding of the various properties of soil colloids. Pochvovedeniye, No. 7-8.

14. TYULIN, A. F. 1949. Colloidal-chemical characterization of the individual soil

fractions. Trudy yubil. ses., posveshchen. 100-letiyu so dnya rezhd. V. V. Dokuchayeva.

15. TSYURUPA, I. G. 1958. Influence of the degree of crystallization of iron compounds on their solubility. Trudy Pochvovennogo instituta Akad. Nauk SSSR. Vol. 53.

16. FIRSOVA, YE. S. 1956. Modification of the Drozdov method of determining free iron oxide. Pochvovedeniye, No. 11.

17. AGUILERA, N. H. and M. L. JACKSON. 1953. Iron oxide removal from soils and clays. Soil Sci. Soc. Amer. Proc. Vol. 17, No. 4.

18. ALLISON, L. E. and G. D. SCARSETH. 1942. A biological method for removing free iron oxides from soil. J. Amer. Soc. Agron., Vol. 34, p. 616.

19. DEB, B. C. 1950. The estimation of free iron oxides in soils and clays and their removal. J. Soil Sci. Vol. I, No. 1, 2.

20. DION, H. G. 1944. Iron oxides removal from clays and its influence on base exchange properties and X-ray diffraction patterns of clays. Soil Sci. Vol. 58, No. 6.

21. DROSDOFF, M. 1941. The determination of free oxides in soil colloids. Soil Sci. Soc. Amer. Proc. Vol. 6, No. 1.

22. DROSDOFF, M. and E. TRUOG. 1933. A method for removing and determining the free iron oxides in soil colloids. Americ. Soc. Agron. Vol. 27, No. 4.

23. DROSDOFF, M. and E. TRUOG. 1935. Mineral constituents of colloidal clay. Soil Sci. Vol. 39, 463.

24. JEFFERIES, C. D. 1941. A method of preparing soils for petrographic analysis. Soil Sci. Vol. 52, No. 6.

25. MITCHELL, B. D. and R. C. MACKENZIE. 1954. Removal of free iron oxides from clay, Soil Sci. b. 77, No. 3.

26. STEFANOVITS, P. 1955. Bestimmung des freien Aluminum-und Eisengehaltes der Böden mittels Komplexon, Agrokemia es Talajtan, Vol. 4, No. 4.

27. TAMM, O. 1922. Om bestämning av de organiska Kompenenterna imarkens gel Komplex. En metod för Studier ov brunjorde och dessin degeneration. Medd. fr. Stat. Skogsförsk., H. 12.

28. TAMM, O. 1934. Über die Oxalatmethode in der chemischen Bodenanalyse. Medd., fr. Stat. Skogsförsk. H. 27.

29. TRUOG, E. and COLLAB. 1936. Procedure for special type of mechanical and mineralogical analysis. Soil Sci. Amer. Proc. Vol. I, No. 1.

USE OF ION EXCHANGE RESINS FOR THE QUANTITATIVE DETERMINATION OF MICROELEMENTS

I. K. TSITOVICH, Kuban Agricultural Institute

The existing methods of quantitatively determining micro-elements in biological samples and especially in soils are complicated by chemical treatments for the separation of admixtures and are rather cumbersome. The determination of available cobalt in the soil by the Peyve method (6) involves the composition of colored compounds of trivalent iron (and other elements) before colorimetry. According to Bamberg (2), investigation of copper and zinc needed by the soil requires the preliminary separation of iron in the form of phosphate. In determining nickel in biological materials one must precipitate 3 times with ammonia to remove the hydroxides of trivalent metals; trivalent iron must be separated beforehand to determine small amounts of cobalt and copper in soils (as well as in animal and plant organisms) according to Malyuge. When determining copper in soil extracts by the Scharrer and Kuhn method, one must remove the color of trivalent iron compounds by reduction with titanium trichloride. Large amounts of trivalent iron also interfere with the determination of manganese in soils and other biological samples, according to Lavrykhina (4).

To determine quantitatively micro-elements (Cu, Co, Ni, Mn, Zn) in soils, salt and especially hydrochloric acid extracts are used (4). Peyve recommends that cobalt available to plants be extracted from the soil with 10% hydrochloric acid, and available copper with 1-N hydrochloric acid (6). Bamberg points out that weak (0.01-N) hydrochloric acid extracts are suitable for determining the need of soils in copper and zinc (2). Therefore, on the basis of our own data on the state of elements of the fourth period in hydrochloric acid solutions (8) and also on the basis of the data of other authors (1, 5), we studied the possibility of the chromatographic separation of bivalent cations, which are the microelements, from trivalent cations, in particular from the iron ion which interferes with the determinations.

Materials and Methods

For this purpose we studied the comparative sorption by ionites of iron (III), manganese (II), cobalt (II), nickel (II), and copper (II) in solutions with hydrochloric acid concentrations from 0.1 to 8 N.

As ion exchange resins we used the strongly acid, monofunctional cationites KU-2 and SBS, and also the strongly acid multifunctional cationite KU-1 (Espatite-1). Before the experiments were begun ionite fractions 0.5-1.0 mm in diameter were separated, all resins were washed of admixtures and converted to H-form.

To be able to compare the sorption of the elements we determined their distribution coefficients amount,ion exchange resins, and hydrochloric acid solutions (1). Exact samples of air-dry ionites were shaken with a definite volume of the solution investigated until equilibrium was reached. Aliquot parts of the solution were taken, and the amount of element not sorbed by the resin was determined colorimetrically: iron and cobalt in the form of rhodanites, manganese in the form of permanganate, nickel in the form of dimetylglyoximate, and copper in the form of ammoniate (3, 7). Then the sorbed amount of the element was calculated in meq/g of resin and the distribution coefficient was determined from the formula:

$$\varphi = \frac{M_1}{M - M_1} \cdot \frac{v}{m},$$

where M_1 is the amount of the element sorbed by the ionite,

M is the total amount of the element in the initial solution,
v is the volume of the solution taken for investigation,
m is the mass of the ionite.

In all our experiments v = 50 ml and m = 0.5 g. The initial solutions, prepared from chemically pure reagents twice distilled, had the following concentrations: 0.1861 mg/ml of iron, 0.2794 mg/ml of manganese, 0.2947 mg/ml of cobalt, 0.2935 mg/ml of nickel, and 0.4765 mg/ml of copper.

Results of the Experiments

Table 1 shows the sorption of micro-elements and iron by various ionites from hydrochloric acid solutions. These data show the general picture of the change in the sorption of the elements with increasing hydrochloric

Table 1

Comparative sorption of microelements by cation exchange resins from hydrochloric acid solutions

Normality of the HCl solution	Sorbed meq/g of resin				
	Fe	Mn	Co	Ni	Cu
		KU-2 cationite			
0,1	0,973	0,750	0,741	0,719	1,1553
0,5	0,527	0,186	0,247	0,280	0,067
1	0,0075	0	0	0,0557	0,011
2	0	0	0	0	0
4	0	0	0	0	0
8	0	0	0	0	0
		SBS cationite			
0,1	0,911	0,430	0,420	0,620	0,725
0,5	0,331	0,131	0,240	0,224	0,117
1	0,050	0,0247	0,050	0,153	0,102
2	0	0	0	0,083	0
4	0	0	0	0,056	0
8	0	0	0	—	0
		KU-1 cationite			
0,1	0,890	0,334	0,381	0,652	0,595
0,5	0,371	0,0217	0,190	0,156	0,047
1	0,142	0	0,0193	0,10	0,0406
2	0	0	0	0,092	0
4	0	0	0	—	0
8	0	0	0	—	0

Note: Comma represents decimal point.

acid concentration. All elements are sorbed by cationites to a considerable degree from relatively diluted hydrochloric acid solutions 0.1-0.5 N). As the acidity of the solution increases, the sorption of the elements decreases rapidly, even though to a different degree for he various microelements. With a hydrochloric acid concentration of more than N there is pracically no sorption of ions by cationites (with he exception of the adsorption of nickel by he SBS resin).

The exchange capacity of ion exchange resins in hydrochloric acid solutions is not equal: micro-elements and iron are best adsorbed by the monofunctional cationite KU-2 and adsorbed least by the multifunctional caionite KU-1.

Table 2 gives the distribution coefficients f iron (III), manganese (II), cobalt (II), nickel II), and copper (II) between the hydrochloric acid solutions and ion exchange resins.

A comparison of the distribution coefficients shows that under all hydrochloric acid soluions concentrations (from 0.1 to 1.0 N by HCl) he trivalent ionic iron is collected more effecively by the cationites than the bivalent microlement ions. This difference is especially sharply pronounced during the adsorption of ons by the resins from the 0.1 N and 0.5 N hydrochloric acid solutions.

The ratios of the distribution coefficients proved to be largest for iron and manganese when adsorbed by the KU-1 cationite from the 0.5 N hydrochloric acid solution; for iron and cobalt when sorbed by the KU-1 resin from the 0.1 N solution; for iron and nickel when adsorbed by the KU-2 cationite from the 0.1 N solution; and for ion and copper when sorbed by the KU-1 ionite from the 0.5 N hydrochloric acid solution.

These data doubtlessly point to the possibility of the quantitative separation of iron from any investigated microelement by means of column chromatography. By using the KU-2 cationite, one may separate trivalent iron from all bivalent microelements simultaneously. Proceeding from this we conducted experiments with artificial mixtures on the separation of iron from microelements.

To separate manganese (II) from iron (III) we proceeded in the following way: columns 10 cm high and 1 cm in diameter were filled with the KU-1 cationite in the H-form, washed with a 0.5 N solution of hydrochloric acid, and introduced into the investigated solutions (0.5 N by hydrochloric acid) containing iron and manganese in various ratios. Then the columns were washed with 0.5 N hydrochloric acid at a

Table 2

Distribution coefficient of micro-elements between hydrochloric acid solutions and cation exchange resins

Normality of the HCl solution	φFe	φMn	φCo	φNi	φCu	$\frac{\varphi Fe}{\varphi Mn}$	$\frac{\varphi Fe}{\varphi Co}$	$\frac{\varphi Fe}{\varphi Ni}$	$\frac{\varphi Fe}{\varphi Cu}$
				KU-2 cationite					
0,1	3726,06	292,95	286,54	256,12	335,44	12,71	13,00	14,47	11,10
0,5	111,88	22,45	32,09	40,03	4,76	4,98	3,48	2,79	23,50
1	0,75	0	0	5,90	0,74	—	—	0,12	1,01
2	0	0	0	0	0	—	—	—	—
4	0	0	0	0	0	—	—	—	—
8	0	0	0	0	0	—	—	—	—
				SBS cationite					
0,1	1007,07	72,46	74,89	169,01	98,65	13,89	13,44	5,95	10,75
0,5	49,47	14,79	31,62	29,01	8,46	3,34	1,56	1,70	5,84
1	4,79	2,49	4,72	21,07	7,43	1,92	1,01	0,22	0,64
2	0	0	0	9,14	0	—	—	—	—
4	0	0	0	5,92	0	—	—	—	—
8	0	0	0	2,28	0	—	—	—	—
				KU-1 cationite					
0,1	877,41	49,98	61,73	187,76	65,76	17,97	14,21	4,67	13,34
0,5	59,19	2,19	19,18	18,49	3,27	27,02	3,08	3,20	18,09
1	16,61	0	1,97	10,54	1,47	—	8,43	1,57	11,29
2	0	0	0	10,16	0	—	—	—	—
4	0	0	0	—	0	—	—	—	—
8	0	0	0	—	0	—	—	—	—

Note: Comma represents decimal point.

Table 3

Separation of manganese (II) from iron (III) by means of KU-1

Mn:Fe ratio	Mn taken, mg	Volume of 0.5-N HCl used on removing manganese, ml	Mn found, mg	Fe taken, mg	Volume of 4-N HCl used on removing iron, ml	Fe found, mg
1 : 1000	0,005	150	0,0047	5,0	250	4,9825
1 : 1000	0,005	150	0,0048	5,0	250	4,8955
1 : 1	0,005	150	0,0049	0,005	100	0,0049
1 : 1	0,005	150	0,0048	0,005	100	0,0050
1000 : 1	5,000	300	4,9355	0,005	100	0,0045
1000 : 1	5,000	300	4,8948	0,005	100	0,0046

Note: Comma represents decimal point.

rate of 1 ml/min to remove the manganese; the filtrate did not give a reaction to iron (III) with ammonium rhodanide. For the following removal of the iron we used 4 N hydrochloric acid. The results of the separation are given in Table 3.

The method of separating copper from iron by means of the KU-1 cationite was analogous to the foregoing; the results of the separation are given in Table 4.

At a ratio of 1:10, the filtrate, obtained as a result of the washing of copper with 0.5 N hydrochloric acid, contained traces of iron. In the case of the separation of mixtures of copper and iron or a ratio of 1:1 or 1000:1, there is no penetration of iron into the filtrate

Table 4

Separation of copper (II) from iron (III) by means of KU-1

Cu:Fe ratio	Cu taken, mg	Volume of 0.5-N HCl used on removing copper, ml	Cu found, mg	Fe taken, mg	Volume of 4-N HCl used on removing iron, ml	Fe found, mg
1 : 10	0,5	100	0,4894	5,0	250	4,2200
1 : 10	0,5	100	0,4885	5,0	250	4,3542
1 : 1	0,5	100	0,4948	0,5	150	0,4982
1 : 1	0,5	100	0,4988	0,5	150	0,4854
1000 : 1	5,0	300	4,8845	0,005	100	0,0048
1000 : 1	5,0	300	4,9600	0,005	100	0,0047

Note: Comma represents decimal point.

Table 5

Separation of cobalt (II) from iron (III) by means of KU-1

Co:Fe ratio	Co taken, mg	Volume of 0.1-N HCl used on removing cobalt, ml	Co found, mg	Fe taken, mg	Volume of 4-N HCl used on removing iron, ml	Fe found, mg
1 : 25	0,2	200	0,1986	5,0	250	4,9900
1 : 25	0,2	200	0,1895	5,0	250	4,8960
1 : 1	0,2	200	0,2000	0,2	100	0,1988
1 : 1	0,2	200	0,1996	0,2	100	0,2000
400 : 1	2,0	400	1,9560	0,005	50	0,0048
400 : 1	2,0	400	1,9850	0,005	50	0,0048

Note: Comma represents decimal point.

uring the washing of copper.

To separate cobalt (II) from iron (III) a olumn 10 cm high and 1 cm in diameter was lso filled with the KU-1 cationite in the H-form, ut was washed with 0.1 N hydrochloric acid. ron and cobalt at various ratios were applied the column in the form of 0.1 N hydrochloric cid solutions. Then the column was washed ith 0.1 N hydrochloric acid at a rate of 1 l/min to remove the cobalt. The iron was emoved with 4 N hydrochloric acid. The esults of the separation are given in Table 5.

A 0.1 N solution of hydrochloric acid prac-cally does not remove any iron (III) from the olumn; there was no iron in filtrates containing obalt.

Conclusions

1. It has been shown that it is possible to eparate iron (III) from manganese (II), cobalt I), nickel (II), and copper (II) microelements hydrochloric acid solutions by means of ationite columns. The use of cation exchange esins in conjunction with existing methods may mplify and facilitate the quantitative deter-ination of microelements.

2. Basic methods have been worked out for separating manganese and iron, cobalt and iron, and copper and iron in hydrochloric acid solutions by means of KU-1. The separation technique could be modified depending on the characteristics of the analyzed material.

The more complicated problem of chromatographically separating the equivalent microelements themselves can apparently also be solved if their varying tendencies for complex formation are used.

Received November 20, 1959

BIBLIOGRAPHY

1. ALIMARIN, I. P., T. A. BELYAVSKAYA, and L. A. BAZHANOVA. 1956. Separation of titanium from accompanying elements by the method of ion exchange chromatography. Separation of titanium and iron. Vestnik Moskovskogo Universiteta. No. 2.

2. BAMBERG, K. K. 1955. Determination of the active forms of calcium, potassium, and phosphoric acid in the soil. In the collection: Methods of agricultural chemical soil investigation. Izd. Akad. Nauk Latv. SSSR. Riga.

3. BABKO, A.K. and A.T. PILINENKO. 1951. Colorimetric analysis. Goskhimizdat.

4. BOBKO, YE.V. 1954. Methods of determining the most important microelements. In the book: Agricultural chemical methods of soil investigation. Izd. Akad. Nauk SSSR. Moscow.

5. BELYAVSKAYA, T.A. and M.K. CHMUTOVA. 1958. Separation of zirconium from chromium and aluminum by the method of ion exchange chromatography. Nauchnyye doklady vysshey shkoly, Khimiya i khimicheskaya tekhnologiya. No. 2.

6. PEYVE, YA.V. 1955. Agricultural chemical methods of soil investigation for the purpose of differentiating the use of fertilizers. In the collection: Methods of agricultural chemical soil investigation. Izd. Akad. Nauk LatvSSR. Riga.

7. SENDEL, YE.B. 1949. Colorimetric determination of traces of metals. Goskhimizdat. Moscow.

8. TSITOVICH, I.K. 1959. State of elements in the center of the fourth period in hydrochloric acid solutions. Doklady Akad. Nauk SSSR. 128 (5).

NITROGEN-FIXING BACTERIA IN THE RED EARTH SOILS OF GEORGIA

N. A. DARASELIYA, Institute of Soil Science, Agricultural Chemistry, and Melioration of the city of Tbilisi

One of the characteristics of red earth soils in the moist subtropics of Georgia as a habitat of plants and microorganisms is their high acidity. The pH of these soils is usually 4.5-5.5. The pH decreases to 4.0 and even 3.8 in tea plantations under prolonged fertilization to which large amounts of ammonium sulfate are added every year.

The high acidity of red earth soils should fully exclude the possibility of the development of the Azotobacter in them if one considers that the optimum pH for this organism, according to the majority of authors (12, 13, 17, 18), is 6.0-8.0.

In many soil investigations in the subtropics the Azotobacter was either not found at all (2, 14), or was extremely weakly developed (7, 8). However, Kuznetsov (11) found the Azotobacter in red earths in compounds prepared according to the method of Vinogradskiy.

When systematically studying the microflora of red earths we always found the Azotobacter on plates of silica gel prepared according to Vinogradskiy and using saccharose for the source of energy. Moreover, we studied the Azotobacter during various periods of the growing season in order to determine the dynamics of its development. In preceding investigations, which were of an exploratory nature, the possibility of the seasonal development of microorganisms in the soil, especially that of the Azotobacter as a non spore-forming microbe (as pointed out by Mishustin [12]), was not taken into account. Our investigations showed that the Azotobacter is present in red earth soils in spite of the reaction unfavorable to it (5, 6).

The amount of Azotobacter in red earths varies from 10% to 50% of the soil lumps cultured in the gel according to Vinogradskiy and increases in the root zone of tea plants. During the growing period the amount of Azotobacter does not remain constant, it increases in summer and decreases in autumn; in certain

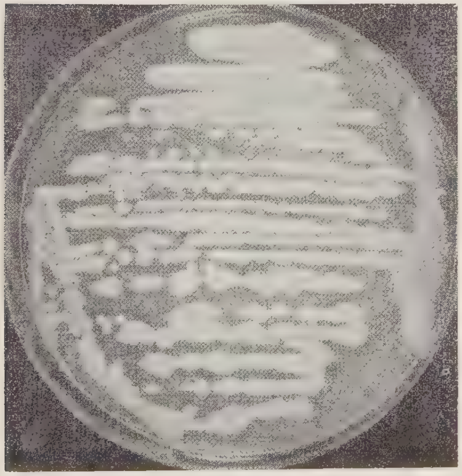


Fig. 1. - Azotobacter indicum, strain No. 4.

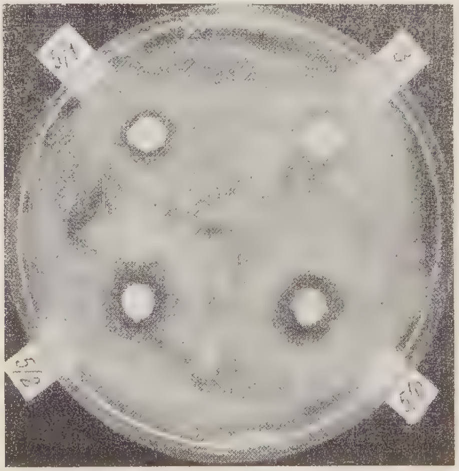


Fig. 2. - Repression of the growth of Azotobacter chroococcum strain No. 6/1 by spore-forming bacteria.

periods it is altogether absent.

We found various species of Azotobacter in red earths: A. chroococcum, A. agile, and A. vinelaudii, but most often a species was found which is close to Azotobacter indicum isolated by Starkey and Dé (22) from Indian soil with a low pH (Fig. 1). The Azotobacter isolated from red earth soil is distinguished by number of characteristics: slow growth, and a copious milk-white, thick slime which acquires a pinkish-brown color with time.

The development of a number of slimy Azotobacter colonies was frequently observed at a time when no growth appeared on the lumps of soil in the gel and at a distance from them; it gave the impression that there is a certain factor in the soil which suppresses the development of the Azotobacter. To clarify this process we analyzed the soils of these lumps and isolated a number of soil bacteria cultures. Further we investigated the antagonistic properties of these bacteria with respect to Azotobacter cultures by the method of superposition of agar blocks (10, 11, 15).

It proved that certain species of spore-forming bacteria act antagonistically toward the Azotobacter, suppressing its growth (Fig. 2). However, this antagonistic action is not the same for the various Azotobacter cultures.

Of the most frequently found strains of soil bacteria investigated by us 76.9% were antagonistic to the No. 6/1 Azotobacter, 69.2% to the No. 6 Azotobacter, 61.5% to the No. 7 Azotobacter, and 15.3% to the No. 4 Azotobacter.

As Table 1 shows, the most active antagonists among the soil microorganisms were cultures No. 5/0, 5/1, and 5/2; 4 and 20 from the Bac. subtilis-mesentericus group, and No. 28, one of the species of Fusarium.

Table 1

Antibiotic action of soil microorganisms on the Azotobacter

Antagonists	Test—Azotobacter cultures			
	№ 6/1	№ 6	№ 7	№ 4
5/0	+	+	+	−
5/1	+	+	+	−
5/2	+	+	+	−
3	−	+	−	−
4	+	+	+	−
1/1	+	+	−	−
20	−	+	+	+
25	+	−	−	−
34	+	−	−	−
28	−	−	+	−
21	+	+	+	+
30	+	−	−	−
24	+	+	+	−
%	76.9	69.2	61.5	15.3

Note: The repression of growth is indicated by the sign +, and the absence of repression by the sign -.

These data explain the constantly observed fact that Azotobacter No. 4 is most frequently isolated during the analysis of red earth soils, while Azotobacter No. 6/1 is found least frequently in red earths. Apparently this can be explained by the fact that the soil contains more antagonists to strain No. 6/1 (Azotobacter chroococcum) and least antagonists to strain No. 4 (Azotobacter indicum).

To judge of the degree of the antagonistic action of soil bacteria with respect to the various species of the Azotobacter we measured the diameter of the zone of Azotobacter growth suppression around the superimposed blocks. As may be seen from Table 2, these zones reached a diameter of up to 15 mm. The largest such zones were obtained for Azotobacter species which are least frequently found in red earths, while the smallest zones were obtained for species most frequently encountered in these soils.

We often observed the formation of 2 zones of growth suppression around superimposed blocks of a greater and lesser diameter. This points to the biological heterogeneity of the Azotobacter cultures. For instance, in culture No. 4 (Azotobacter indicum) the first zone around the block was completely clear, while the second consisted of Azotobacter satellites.

Thus the preferential development of definite species of the Azotobacter in red earths is governed by the antagonism of certain soil bacteria. Our data fully confirm the opinion of Krasil'nikov (10) that the specificity of the antibiotic action makes it possible to make a rather clear distinction between species of microorganisms. After investigating the antagonistic properties we were able to establish a greater variety of species of various Azotobacter strains than before.

The foregoing data allow us to conclude that, in addition to the unfavorable reaction of the medium, one of the factors which limits the

Table 2

Comparative activity of the antibiotic properties of soil bacteria (diameter of the growth repression zone, mm)

Azotobacter	Antagonists			
	№ 5/0	№ 5/1	№ 5/2	20
№ 3	12	9	12	15
№ 5a	13	5	10	10
№ 5	11	7	10	10
№ 6/1	11	4	8	10
№ 4	4	2	3	0
№ 6в	0	5	2	0
№ 7	1	1	2	5

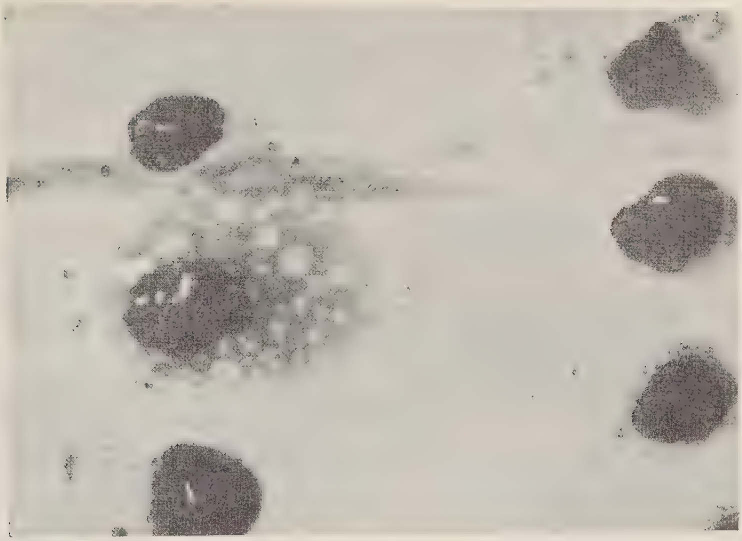


Fig. 3. - Slimy lump of soil during the isolation of the Azotobacter on silica gel; gas bubbles from the butyric acid fermentation caused by Clostridium pasteurianum accompanying the Azotobacter can be seen.

evelopment of the Azotobacter in red earths the presence of antagonists.

In addition to the Azotobacter, another nitro- en-fixing bacterium — Clostridium pasteurianm is constantly found in red earth soils. Its umber reaches tens and hundreds of thousands 1 g of soil. During individual periods of nalysis, the slime around the lumps of soil the silica gel according to Vinogradskiy as riddled by gas bubbles (Fig. 3); when uch a soil lump was placed in a test tube with corresponding medium, intense butyric acid rmentation developed, while in the sediment the bottom of the tube characteristic Clostriium cells were found.

In vegetation-free experimental plots where e studied the microflora of red earths, the lostridium content decreased when mineral rtilizers were applied which decrease the H of the soil; in soils of similar plots where a plants were sown, there was no such derease under the same conditions and the lostridium content was more or less stable nd high during all investigation periods.

The literature gives numerous data on the ide distribution of Clostridium pasteurianum soils in general and in particular in soils here the Azotobacter does not develop or evelops weakly (3, 4, 16, 21). Shklyar (19, 20) owed the positive effect of Clostridium on e yield of a number of field crops and also nfirmed the ability of Clostridium pasteurianum develop well under aerobis conditions when own together with the Azotobacter.

All these data and our observations on the ture of the development of nitrogen-fixing cteria — Azotobacter and Clostridium, point the fact that the latter, being less particur as to the reaction of the soil and developing in great numbers in red earth soils, may play the main role in the fixation of nitrogen in them.

Received December 23, 1959

BIBLIOGRAPHY

1. AFRIKYAN, E. K. 1954. Antagonistic action of spore-forming bacteria on Azotobacter cultures. Trudy Instituta mikrobiologii. Vol. 3.
2. GARDER, A. A. 1928. Microbiological characterization of soils in the Chakvin rayon, Batumi Okrug. Trudy Otd. s.-kh. mikrob. Gos. in-ta opyt. agronomii. Vol. 3.
3. VOZNYAKOVSKAYA, YU. M. 1959. Importance of nitrogen fixation in soil by non-symbiotic microorganisms. Agrobiologiya.
4. VOZNYAKOVSKAYA, YU. M. and A. S. RYZHKOVA. 1954. Influence of a mixture of organic and mineral fertilizers on soil microflora. Dokl. VASKHNIL. No. 6.
5. DARASELIYA, N. A. 1950. Development of the Azotobacter in the rhizosphere of the tea shrub. Pochvovedeniye, No. 1.
6. DARASELIYA, N. A. 1950. Microflora of the rhizosphere of the tea shrub. Byul. In-ta chaya i subtrop. kul'tur. No. 3.
7. ZAKHAROVA, G. O. and A. A. OBRAZTSOVA. 1937. Development of the Azotobacter in the red earth soils of humid subtropics. Tr. In-ta fiziol. rast. 1(2).

8. ISAKOVA, A. A. 1937. Distribution of the Azotobacter in the rhizosphere of subtropical crop. Tr. In-ta fiziol. rast. 1(2).

9. KRASIL'NIKOV, N. A. 1958. Soil microorganisms and higher plants. Izd. Akad. Nauk SSSR.

10. KRASIL'NIKOV, N. A. 1958. Antagonism of bacteria and antibiotic substances. Izd. Sov. nauka.

11. KUZNETSOV, S. I. 1933. Microbiological characterization of certain regions of the Trans-Caucasus. Tr. NIU, No. 108, Mikrobiologiya pochvy i udobreniya. Vol. 2.

12. MISHUSTIN, YE. N. 1954. Ecogeographical distribution of the Azotobacter in the soils of the USSR. Tr. In-ta mikrobiologii. Vol. 3.

13. MISHUSTIN, YE. N. and M. I. SEMENOVICH. 1933. Soil acidity as a factor determining the appearance in the soil of the inactive Azotobacter. Mikrobiologiya 8(1).

14. OBRAZTSOVA, A. A. 1937. Microorganisms of the rhizosphere of certain subtropical plants. Tr. In-ta fiziol. rast. 1(2).

15. RYBALKINA, A. V. 1949. Microflora of peat and its relation to Azotobacter chroococcum and higher plants. Pochvovedeniye, No. 4.

16. RYBALKINA, A. V. 1957. Microflora of soils in the European USSR. Izd. Akad. Nauk SSSR.

17. SUSHKINA, N. N. 1949. Ecogeographical distribution of the Azotobacter in the soils of the USSR. Izd. Akad. Nauk SSSR.

18. FEDOROV, M. V. 1954. Soil microbiology. Izd. Sov. nauka.

19. SHKLYAR, M. Z. 1951. Interaction between the Azotobacter and Clostridium pasteurianum in a mixed culture. Tr. In-ta s.-kh. mikrobiologii. Vol. 11.

20. SHKLYAR, M. Z. 1958. Problem of the interrelationship between the Azotobacter and Clostridium pasteurianum. Tr. Vses. in-ta s.-kh. mikrobiologii. Vol. 15.

21. WAKSMAN, S. 1952. Principles of soil microbiology. John Wiley and Sons.

22. STARKEY, R. and DÉ. 1939. A new species of Azotobacter. Soil Science. 47 (4).

TRANSFORMATION OF UREA IN THE SOIL

A. F. KALINKEVICH, All-Union Scientific Research Institute of Fertilizers and Agricultural Soil Science

At the present time it is an accepted fact that when synthetic urea is applied to the soil it rapidly (within days even) ammonifies under the influence of urea-bacteria, secreting the ferment urease:

$$CO(NH_2)_2 + 2H_2O = (NH_4)_2CO_3$$

As a result, this synthetic urea is considered as pure ammonium fertilizer. This belief is based on extensive investigations by French scientists (5, 6) and Turchin in the USSR (2, 3, 4).

On the basis of his experiments and investigations, F. V. Turchin concluded that: "Urea rapidly transforms in the soil into the ammonia form. Large amounts of urea, exceeding the normal field dosage, are fully hydrolyzed in the soil within 24 hours" (3-4). As a result Turchin considers urea as ammonium fertilizer. However, experimental material on the comparison of various forms of nitrogen fertilizers does not always correspond to such an idea. In a number of experiments urea proved to be a highly effective nitrogen fertilizer, surpassing ammonium bicarbonate. This can occur only in the case when it directly serves as a source of plant nutriant, i. e., when it does not change into ammonium salts for a long time.

A thorough study of the effectiveness of urea when added to the soil caused us to doubt whether such a rapid transition, as stated previously, of urea into ammonium bicarbonate occurs under natural conditions. Are not the results obtained in the experiments of Turchin consequences of the peculiarities of the method used, which does not reflect the processes actually taking place in the soil?

In Table 1 we give the results of soil temperature observed in 1959. This year was characterized by very high air temperatures in July-August, reaching up to 40°C and more (1). The soil temperature at a depth of 10 cm, where the main root mass was located, was 6.9°C in April, 12.9°C in May, 20.4°C in July, and 19.0°C in August. In the experiments of Turchin the temperature was 25°-27°C, which is not normal for the soil, but an exception.

In relation to the foregoing we made it our task to observe the disappearance of urea in the soil at various temperatures.

Experimental Method

In our experiments the method differed somewhat from that used by Turchin. Instead of 150 g of soil for composting we took 6 kg. Instead of determining urea from its decomposition by urease, which caused great objections, we used a chemical method. We used the comparatively poor, medium clay loam sod-podzolic soil of the Baryba central experiment station of the All-Union Institute of Fertilizers and Agricultural Soil Science. Before the soil (6 kg) was placed into glass pots, we added fertilizers to it in the form of solution and mixed it well with the soil. We replicated the experiment twice.

Experimental setup: 1. Control; 2. Ammonium bicarbonate, $(NH_4)_2CO_3$; 3. Urea $CO(NH_2)_2$.

When the pots were being filled, 281 g of nitrogen per 1 kg of soil were added in the first experiment (Fig. 1) and 257 mg per 1 kg of soil, in the second (Fig. 2). The amount of nitrogen in the solution was determined before it was added to the soil and in water extracts from it immediately after the pots were filled. The first and second experiments were made in order to determine whether there was any urea of other forms of nitrogen in the soil which could have been determined together with the urea.

The pots were kept at 60% of total moisture capacity throughout the experiment. The pots were placed in biological thermostats at a given temperature.

Principle of Determination of Urea in the Soil. Urea is easily removed from the soil by water; a number of other nitrogen compounds, in particular a certain amount of ammonia also enters the water extract. In the experiments we separated urea from ammonia by means of cation exchange sorbents. When the water extracts from the soil were filtered through columns filled with cationites, the ammonia was adsorbed and urea passed into the filtrate, where it was determined.

Soil samples were taken periodically and their water extracts were analyzed giving us the possibility of observing the presence of urea in the soil from the moment it was added

Table 1

Soil temperature (°C) at a depth of 10 cm according to data from the Meteorological Observatory of the K. A. Timiryazev Moscow Academy of Agriculture, 1959

Month	10-day period	Time of observation, hour				Average
		1	7	13	19	
April	1	0,2	0,4	1,6	0,7	0,7
	2	5,6	5,5	8,7	7,8	6,9
	3	6,0	5,8	8,2	7,4	6,8
May	1	9,9	9,8	12,3	11,6	10,9
	2	9,7	9,9	11,9	11,1	10,6
	3	11,6	11,6	14,8	13,6	12,6
June	1	13,0	13,6	17,2	16,1	15,0
	2	15,6	15,7	18,2	17,4	16,7
	3	14,9	14,3	17,3	16,3	16,1
July	1	17,9	17,9	20,9	19,6	19,1
	2	18,5	19,0	23,1	21,0	20,4
	3	18,4	18,9	22,8	21,0	20,3
August	1	17,7	17,7	21,3	19,5	19,0
	2	16,2	16,5	19,8	18,3	17,7
	3	15,2	14,9	17,4	16,2	15,9
September	1	11 8	11,7	13,9	12,9	12,6
	2	11,1	10,7	12,1	11,4	11,3
	3	8,4	8,2	9,4	8,7	8,7

Note: Comma represents decimal point.

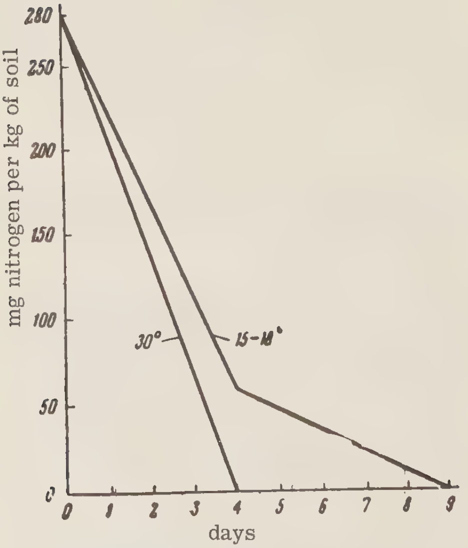


Fig. 1. - Transformation of urea in the soil at high temperatures.

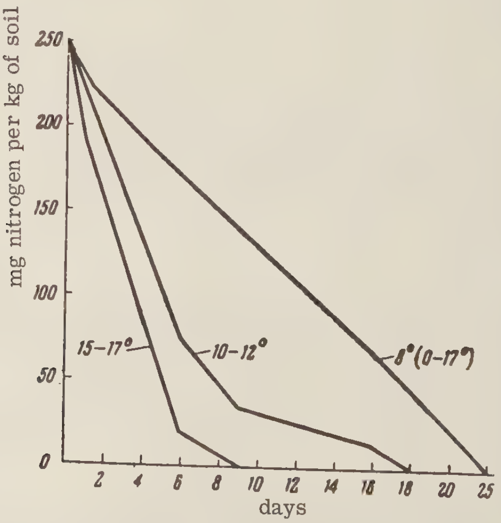


Fig. 2. - Transformation of synthetic urea in the soil at various temperatures.

to the soil.

Method of Filling the Columns for Absorption of Ammonia from the Water Extract from the Soil. A filter consisting of a small amount of glass wool was placed in front of the stopcock of a 100 ml buret so that the sorbent would not penetrate into the extract. The buret was filled up to 40 cm with sulfocarbon in the H-form which was previously washed with hydrochloric acid for 12 hours.

After that 1.5 liter of a 2% solution of HCl were filtered through the columns until there was no reaction to iron in the filtrate (test with KCNS) and then washed with deionized water with a pH of 6.2. Then the sulfocarbon was changed from the H-form to the K-form by washing the columns with 500 ml of a mixture of a 5% solution of KCl + 0.1% KOH to prevent the hydrolysis of urea. Then the columns were washed with deionized water until the pH reached 6.2 (according to the method of Alyamovskiy) and there was no chloride in the filtrate (reaction to $AgNO_3$).

To verify the columns thus prepared we filtered pure solutions of ammonium bicarbonate, urea, and deionized water through them. No ammonia was found in the filtrate which was passed through the columns where the solution contained ammonium bicarbonate; it had been fully adsorbed by the cationite in the columns.

When the urea solution was filtered through the columns it was not adsorbed there and fully penetrated into the filtrate.

The same was observed when water extracts from the soil to which ammonium bicarbonate and urea were added previously were filtered through the columns. There was also no urea in the water extracts from the control vessels.

The water extract from the soil was filtered through the columns and washed with water at a rate of 1 ml/min per cm² of the area of the buret. A prerequisite for the normal operation of the columns was the absence of air in the sorbent layer.

Method of Determining Urea in the Soil. A borer was used to take soil samples at 3 places (a total of 300 g) from a depth of 2/3 of the pot at time intervals indicated in the figures. After thorough mixing, 2 samples were taken from each pot for soil moisture determination and 2 samples for urea determinations. Two hundred milliliters of deionized water were poured over 50 g of soil. The flasks were agitated for 5 min in a rotator, and then the suspension was filtered through Gouch funnels. Fifty milliliters of the transparent filtrate were placed in the columns filled with cationites (as described previously) and washed with deionized water into 250 ml volumetric flasks. This amount of solution (filtrate) was transferred into Kjeldahl flasks (in conformity with GOST No. 2081, 1957) filled with sulfuric acid and the urea was hydrolyzed into ammonia on gas burners in the same way that a plant mass is ashed to determine nitrogen. Then the solution was transferred into a volumetric flask and brought to volume. From this, samples were taken for distilling ammonia in the Kjeldahl apparatus.

All data given in the figures are averages for 2 pots and 2 determinations of ammonia in each pot.

Experimental Results

Figures 1 and 2 show the results of 2 experiments. They show that urea disappears very rapidly from the soil at a temperature of 30°C. With this the observations made by Turchin 30 years ago are confirmed, using a modified experimental setup and method of determining urea. At a temperature of 15°-17°C, 1/4 of the urea disappeared from the soil in the first 24 hrs., and 12/13 on the sixth day, while it disappeared completely by the tenth day.

At a temperature from 10°-12°C, 1/12 of the urea disappeared from the soil after 4 days, 1/2 on the sixth day, 7/8 on the ninth day, and the urea disappeared completely between the sixteenth and nineteenth days.

At a temperature of 0°C at night and up to 17°C during the day 1/12 of the urea disappeared in the first day, 1/4 after 4 days, 1/3 after 6 days, 2/3 on the ninth day, 3/4 on the sixteenth day and completely after 22 days.

Thus, the results of former investigations were confirmed by the foregoing 2 experiments which showed that urea added to the soil disappears very rapidly at high temperatures (25°-30°C). But such a temperature occurs very rarely in nature. As the soil temperature drops, the rate at which urea disappears decreases sharply. At a temperature from 15°-17°C urea disappeared in our experiments on the ninth day and at a temperature of 10°-12° by the sixteenth day.

The method used by Turchin and by us does not allow one to determine whether urea changed into ammonia under the influence of urease, or whether it was absorbed by microorganisms and then decomposed by the latter, giving ammonia.

Thus our experiments showed that the transformation rate of urea depends on soil temperature. The higher the temperature, the more rapidly does urea disappear from the soil. At the normal temperatures observed in the plowed layer of the soil, the synthetic urea added to the soil is preserved for a long time and its amide nitrogen may serve as a direct source of plant nutrition.

Received July 23, 1960

BIBLIOGRAPHY

1. Byulleten' meteorologicheskoy observatorii Moskovskoy sel'skokhozyaystvennoy akademii im. K. A. Timiryazeva. 1959.

2. TURCHIN, F. V. 1931. Transformation of urea in the soil. Udobreniye i urozhay. No. 6.

3. TURCHIN, F. V. 1935. Agricultural chemical study of urea. Mineral'nyye udobreniya i insektofungisidy. No. 2.

4. TURCHIN, F. V. 1960. Urea. Handbook on mineral fertilizers. p. 106. Sel'khozgiz.

5. BORDAS. 1929. Annales de la Science Agronom. et Mathieu. No. 6.

6. GIBSON, T. 1930. Journal of Agricultural Sci. 20:4.

BIBLIOGRAPHY

FACTORS OF SOIL FORMATION, GENESIS, AND GEOGRAPHY OF SOILS

1. AZARINA, V. A. 1959. Certain results of the study of sod-carbonate soils of the Central Cis-Urals. Tr. (Permsk. s.-kh. in-ta). 17(2):122-134. Bibliog. 5 refs.

2. BAGROV, YU. N. 1960. Compact chernozems and ways of improving them. S. kh. Sev. Kavkaza. No. 11:19-21.

3. BOCHAROV, A. P. 1960. Profiling the soil surface by the photographic method. Tr. N-i. in-ta mekhanizatsii i elektrifikatsii s. kh. (Kazakh. akad. s.-kh. nauk). Vol. 4:396-401.

4. ISLAMOV, A. I. 1960. Loess of the Tashkent deserts. Doklady Akad. Nauk Uzb SSR. No. 9:29-32. Summary in Uzbek.

5. KAMYNIN, M. I. 1959. Brief characterization of the soils at the Novozybkov agricultural station of the All-Union Institute of Fertilizers and Agricultural Soil Science. Tr. (Novozybkovskaya op. st.). No. 2:17-25.

6. KARAVAYEV, V. N. 1960. Soil-formation conditions and soil provinces in the Central Kama region. Tr. Ural'sk. n.-i. inta s. kh. Vol. 2:80-95, with maps. Bibliog. p. 95.

7. MAMYTOV, A. M. 1960. Soils of the stony deserts of Kirgizia. (Gray-brown stony desert mountain soils). Izv. Kirgiz. filiala Veseoyuz. geogr. o-va. No. 2:59-71. Bibliog. 22 refs. Summary in Kirgiz.

8. OTORBAYEV, K. O. 1960. Results and problems of geographical and soil investigations in Kirgizia. Izv. Kirgiz. filiala Vsesoyuzn. geogr. o-va. No. 2: 5-10. Summary in Kirgiz.

9. POPOV, L. V. 1960. Soils of the northwestern part of the Bratsk rayon. Tr. Vest.-Sib. filiala (Sibirsk. otdeleniye Akad. Nauk SSSR). No. 22:12-30. Bibliog. p. 30.

10. PONOMAREVA, V. V. 1960. Characteristics of soil formation on gypsum bearing rocks in the taiga zone. (Photogenic metamorphosis of $CaSO_4 \cdot 2H_2O$-$CaCO_3$). Doklady Akad. Nauk SSSR. 134(5):1196-1199. Bibliog. 5 refs.

11. PROTASOVA, L. A. 1959. Soils developed on Permian clays under conditions of the Central Cis-Urals. Tr. (Permsk. s.-kh. in-ta). 17(2):135-153. Bibliog. p. 153.

12. ROYCHENKO, G. I. 1960. Mountain-forest soils of Kirgizia and problems of their study. Izv. Kirgiz. filiala Vsesoyuz. geogr. o-va. No. 2:73-78. Bibliog. 18 refs. Summary in Kirgiz.

13. SAVINOV, B. I. 1959. Certain characteristics of soil formation in the western part of the Terek River delta. Tr. Vsesoyuz. s.-kh. in-ta zaoch. obrazovaniya. No. 2: 86-94.

14. SEREBRYAKOV, A. K. 1960. Soils of the Eastern division of the State Reservation of the Caucasus. Sb. tr. in-ta (Stavrop. ped. in-t). No. 18:89-119, with maps. Bibliog. 29 refs.

15. TOLCHEL'NIKOV, YU. S. 1960. Mineralized roots in the soils of deserts. Priroda, No. 10:84-85.

16. SHCHERBAK, F. I. 1959. Soil-melioration and climatic conditions of the Botanical Garden of the Pyatigorsk Pharmaceutical Institute. Uchen. zap. (Pyatigorsk. farmatsevt. in-t). Vol. 4:284-291. Bibliog. 6 refs.

17. BILLINGS, W. D., and H. A. MOONEY. 1959. An apparent frost hummock-sorted polygon cycle in the alpine tundra of Wyoming. Ecology, vol. 40(1):16-20.

18. BLACKBURN, G. 1959. The soils of County Grey, South Australia. CSIRO Div. Soils, Soils Land Use Ser., No. 33, 71 pp.

19. HIDEAKI SAEKI, et al. 1959. Physical and chemical properties of Cambodian soils. Sci. Repts. Agr. Exped. Cambodia, Part 2, pp. 1-46. Ref.: Chem. Abstr., 1960, 54(12).

20. LAG, J., and E. MORK. 1959. Iordsmonnet i Ulvsjoberget forsoksomrade. Medd. Norske Skogsfors Vesen, 53, 41 pp. Soils of the Ulvsjoberget experimental area.

21. TOMASZEWSKI, J. 1959. Soil-forming and typological soil processes. Wroclaw, 50 pp.

MINERALOGY

22. BAILEY, G. W., and J. L. WHITE. 1959. The mineralogy and genesis of a Soil (Tilsit Silt Loam) of the unglaciated region of Indiana. Proc. Indiana Acad. Sci., 68, 337 pp. 42.

23. BERNAL, J. B., et al. 1959. The oxides and hydroxides of iron and their structural interrelationships. Clay Minerals Bull. 4(21):15-30.

24. BONIFAS, M. 1959. Contribution a l'etude geochimique de l'alteration lateritique. Mem. Serv. Carte geol. Alsace-Lorraine. No. 17, 159 pp.

25. DIXON, J. B., and M. L. JACKSON. 1959. Dissolution of interlayers from intergradient soil clays after preheating at 400° Sci., 129(3363): 1616-1617.

26. FRANOOMBE, M. N., and H. F. ROCKSBY. 1959. Structure transformations effect by the dehydration of diaspore, goethite and delta ferric oxide. Clay Minerals Bull. 4(21):1-14.

27. GONZALES, GARCIA S. 1959. Comparative study of some methods of investigating clays in Soils. An. Edafol. Fisiol, veg., 18:723-744. In Spanish.

28. HANDY, R. L., and T. DEMIREL. 1959. Notes on determination of carbonates in soils by chemical means, differential thermal analysis, and X-ray. Proc. Iowa Acad. Sci., 66:222-236.

29. KANNO, I., et al. 1959. Chemical properties and clay minerals of andesitic volcanic-ash soils developed on the Kikuchi Table Land, Kyushu. Bull. Kyushu agric. Exp. Sta., 5:277-310. In Japanese.

30. KASHKAR, M. A. 1959. The hydrothermal and hydrothermalmetasomatic formation of kaolin and a genetic classification of clay rocks. Clay Minerals Bull., 4(21): 44-51. Bibliog. pp. 50-51.

31. MACKENZIE, R. C. 1959. The classification and nomenclature of clay minerals. Clay Minerals Bull., 4(21):52-66. Bibliog. pp. 65-66.

32. MITCHELL, B. D., and R. C. MACKENZIE. 1959. An apparatus for differential thermal analysis under controlled-atmosphere conditions. Clay Minerals Bull., 4(21): 31-43.

33. The thermal decomposition of NH_4-montmorillonites. Part I. 1959. Clay Minerals Bull., 22:81-87.

34. THOMAS, G. W. 1959. Salt desorption from halloysite. Nature, No. 4700, p. 1746. Bibliog.

PHYSICAL PROPERTIES OF SOILS, METHODS OF INVESTIGATION

35. BAT'KAYEV, ZH. YA. 1960. Change of the structure of soil on dark sierozem under the influence of cotton. Doklady Kazakhsk. akad. s.-kh. nauk. No. 2:63-70. Bibliog. 13 refs. Summary in Kazakh.

36. BULULUKOV, YU. G., and K. K. GALAKTIONOVA. 1960. Moisture of soils in the mountains in relation to the surface condition. Tr. Chatkal'skoy gornomeliorat. op. st. No. 1:75-102.

37. VASIL'YEV, M. D., and P. G. KUKHAR'. 1960. Dynamics of the soil moisture regime in clean fallow. Tr. Ural'sk.n.-i. in-ta s. kh. Vol. 2:46-59. Bibliog. p. 59.

38. GLEYBERZON, D. A. 1960. Soil profilograph with a movable pantograph. Tr. N.-i. in-ta mekhanizatsii i elektrifikatsii s. kh. (Kazakh. akad. s.-kh. nauk). Vol. 4:455-459.

39. GROMOV, K. M. 1960. Experimental study of the soil moisture regime in the Khibiny Mountains. Tr. Khibinsk. geogr. stantsii. No. 1:131-163. Bibliog. 8 refs.

40. DRUZHININ, D. 1960. Soil structure in individual crop rotation fields. S. kh. Sibiri. No. 11:24-26.

41. ZHDANOVA, YE. I. 1959. Moisture and temperature regime of drained peat soils in winter. Tr. Vsesoyuz. s.-kh. in-ta zaoch. obrazovaniya. No. 2:256-262. Bibliog. 7 refs.

42. KARIMOV, A. 1960. Influence of various methods of mulching on the temperature and moisture of the soil. Doklady Akad. Nauk UzbSSR. No. 8:48-51. Summary in Uzbek.

43. KARPOV, S. F. 1960. Moisture dynamics of mountain soils. Tr. Chatkal'skoy gornomeliorat. op. st. No. 1:55-74.

44. KOLOSOVA, A. A. 1959. Moisture regime of sandy soils in relation to the deepening of the plowed layer. Tr. (Novozybkovskaya op. st.). No. 2:265-271.

45. MANEVICH, SH. S. 1959. Absorption method for evaluating the moisture content of very moist media. Tr. Kazansk. s.-kh. in-ta. 3(42):147-149.

46. RUBASHOV, A. B. 1960. Reversibility of water-stable soil aggregates. Vestn. s.-kh. nauki. No. 9:50-54. Bibliog. 6 refs.

47. SOSNIN, V. A. 1960. Method of determining the degree of mixing of soil under deep cultivation and plowing without a moldboard. Tr. N.-i. in-ta mekhanizatsii i elektrifikatsii. s. kh. (Kazakh. akad. s.-kh. nauk). Vol. 4:132-136.

48. FILATOV, M. P. 1960. Influence of structure on soil moisture. S. kh. Sev.-Zap.

zony. No. 10:68-69.

49. KHACHATRYAN, KH. A. 1960. A new method of determining the degree of friability of the soil. Sb. nauchn. tr. (Armyansk. s.-kh. in-t). No. 11(2):85-91. Summary in Armenian.

50. BREWER, R., and J. R. SLEEMAN. 1960. Soil structure and fabric. Their definition and desorption. J. Soil Sci., II, No. 1, pp. 172-185. Bibliog. 18 refs.

51. ELRICK, D. E., et al. 1959. Tests of capillary flow scaling. Soil Sci. Soc. America Proc., 23(5):329-332.

52. EMERSON, W. W., and M. G. DETTMANN. 1960. The effect of pH on the wet strength of soil crumbs. J. Soil Sci., II, No. 1: 149-158. Bibliog. 21 refs.

53. FLAIG, N., and H. KEPPEL. 1960. Atomphysik im Dienste der Bodenforschung. "Mitt. Dtsch. Landwirtschaftsges" 75(33):1023-1025.

54. LEFEVRE, G., and P. LEFEVRE. 1959. Essai de tri mecanographique sur les elements de l'analyse physique des sols du prateau Picard de l'Oise. Ann. Agron., Ser. A, ann. 10, No. 1:53-68.

55. LUGO-LOPEZ, M. A., and J. JUAREZ. 1959. Evaluation of the effects of organic matter and other soil characteristics upon the aggregate stability of some tropical soils. J. Agric. Univ. Puerto Rico, 43:268-272.

56. MATSUO, H., and SATO Y. 1959. Studies on the water permeability of paddy soils. I. Sampling and measuring methods for the permeability of paddy soils. Bull. Kyushu agric. Exp. Sta., 5:259-267. In Japanese.

57. RICHARD, F. 1958-1959. Wasserhauchalt und Durchlueftung im Boden. Ber. geobot. Forschinst. Ruebel. A review—with 23 references, pp. 76-90.

58. PILLSBURY, A. F. 1959. The physical aspects of soil management. Natural resources. N. Y. —London. pp. 200-220.

59. SHAFFER, G. 1906. Eine Methode der Abscherwiderstandsmessung bei Ackerböden zur Beurteilung ihrer Strukturfestigkeit im Felde. Landwirtsch. Forsch., 13(1):24-33.

60. SILLAPAA, M. 1959. The influence of some physical soil properties on subsoil structure. Helsinki, 24 pp. (Agrogeol. julkaisuja, No. 75). Bibliog. pp. 19-21.

SOIL CHEMISTRY AND METHODS OF ANALYSIS

61. BUYANOVSKIY, G. A. 1960. Observations on the oxidation-reduction potential of soils under laboratory experiment conditions. Doklady Akad. Nauk AzSSR. 16(7): 689-692. Summary in Azerbaydzhan.

62. DVORKOVICH, B. 1960. New instruments for determining soil acidity. Kolkhoz. proizvodstvo. No. 10:42.

63. DUKHANIN, A. A., and A. A. KOLOSOVA. 1959. Change in the nitrate and soluble P_2O_5 content of soil under the influence of 2, 4-dichlorphenoxyl acetic acid. Tr. (Novozybkovskaya op. st.). No. 2:299-307.

64. KAURICHEV, I. S., YE. M. NOZDRUNOVA, and M. N. RYTIKOVA. 1960. Qualitative composition of humus in sod-podzolic soils which are temporarily supersaturated. Izv. Timiryaz. s.-kh. akad. No. 5:101-113. Bibliog. p. 113.

65. KOREN'KOV, D. A. 1960. Nitrogen-containing polymers. Vestn. s.-kh. nauki. No. 10:49-53. Bibliog. 7 refs.

66. KOROTAYEV, N. YA., V. A. AZARINA, T. V. VOLOGZHANINA, and L. A. PROTASOVA. 1959. Problem of the content of microelements in the soils of the Perm Oblast'. Tr. (Permsk. s.-kh. in-t). 17(2): 116-121, with tables.

67. MAZAYEVA, M. M., O. V. NEUGODOVA, and K. M. KHOVANSKAYA. 1960. Trilonometric method of determining calcium and magnesium during agricultural chemical investigations. Zemledeliye, No. 11:71-75.

68. MOSHEV, A. I. 1959. Problem of the method of determining the absorption capacity of soil colloids. Tr. (Permsk. s.-kh. in-t) 17(2):154-159. Bibliog. 9 refs.

69. TSYRULIK, M. I. 1960. Leaching of nitrates from the soil. S. kh. Sev. Kavkaza. No. 11:89-90.

70. SHABALINA, G. A. 1960. Certain data on the composition of humus in sod-podzolic and sod-carbonate soils in the Estonian SSR. Izv. Akad. Nauk EstSSR. Ser. biol. No. 3:254-261. Bibliog. 13 refs. Summary in Estonian.

71. BUROCK, H. C. 1960. Kolorimetrische Mikro-Kjeldahl-Methode mit direkter Nesslerisation zur routinemassigen Stickstoffbestimmung. Mikrochimica Acta, 2:200-203.

72. BOURRIER, J., et al. 1960. Mesure pratique de la vocation des sols a la retention des radio-elements. Compt. rend. Acad. agric. France, No. 6:349-352.

73. EDSON, S. N., V. W. JOHN. 1959. The Comber soil acidity test for soluble iron in Azalea soils. Proc. Florida State Hort. Soc., 72:380-383.

74. ERIKSSON, E. 1960. The yearly circulation of chloride and sulfur in nature: meteorological, geochemical and pedological implications. Part 2. Tellus, 12:63-109. Ref.: Soils and Fertilizers, 1960, No. 4: 1504.

75. ERNST, J.W., and H.F. MASSEY. 1960. The effects of several factors on volatilization of Ammonia, formed from urea in the soils. —Soil Sci. Soc. America Proc., No. 2:87-90.

76. FINC, L.O., E.J. WILLIAMSON, F. WIERMIA, and C.R. UNBACK. 1959. A study of the sodium adsorption ratio and residual sodium carbonate concepts of irrigation waters as they affect exchangeable sodium of soil under semiarid conditions. Soil Sci. Soc. America Proc., Vol. 23(4):263-266.

77. GALLEGO, R., and E. LABORDA. 1959. Distribution of iron between different particle-size groups of soil. An. Edafol. Fisiol. veg., 18:783-795. Japanese.

78. GALOPPINI, C., and G. LOTTI. 1959. Investigations on the distribution and fixation of boron in soils of Pisa province. Ann. Fac. Agr. Pisa, 20:145-152. In Italian.

79. GEEL, K.H., and R. AGARWAL. 1960. Total and organic phosphorus in different size-fractions in genetically related soils of Kanpur in the Indian Gangetic Alluvium. J. India Soc. Soil Sci., 8(9):17-22.

80. GEREI, L. 1959. The effect of salt composition in the dynamics of iron in meadow-solonets soils. Agrartud. Egyet mesögazd. Kar. Közl., pp. 247-253. In Hungarian.

81. GHOSH, S.K. 1959. Effect of potassium chloride on nitrate formation in humus rich soil by the application of nitrogenous compounds. Proc. nat. Inst. Sci. India, 25:307-314.

82. HANDY, R.L., and E.A. ROSAUER. 1959. X-ray fluorescence analysis of total iron and manganese in soils. Proc. Iowa Acad. Sci., 66:237-247.

83. HARTGE, K. 1960. Die Auswertung von pF-Kurven. Pflanzenernähr. Dung., Bodenkunde, 88(3):221-227.

84. HSU PA HO, and C.I. ROCH. 1960. Aluminum fixation in a synthetic cation exchanger. Soil Sci. Soc. Amer. Proc., 24(1):21-25.

85. SCHAEFER, R. 1960. Sur la dynamique du complexe uronique dans les sols hydromorphes mesotrophiques. Compt. Rend. Acad. Sci., 250(18):3067-3067. Bibliog. 7 refs.

86. VECERA, M., and L. SYNEK. 1960. Ein Schnellverfahren zur Stickstoff—Mikrobestimmung in organischen Substanzen unter Verwendung von Co_3O_4 als Verbrennungskatalysator. 26. Mitteilung über quantitative organische Analyse. Mikrochimica Acta, 2:208-219.

BIOLOGY AND MICROBIOLOGY OF SOILS

87. ALIMDZHANOV, R.A. 1960. Soil fauna of Uzbekistan. S. kh. Uzbekistana. No. 9: 90-91.

88. BYCHKOVSKAYA, A.L. 1960. Selective utilization of butyric acid by certain aerobic soil microorganisms. Mikrobiologiya. 29(5):704-709, with tables. Bibliog. 7 refs.

89. GALSTYAN, A.SH. 1960. Investigation of the fermenting activity of bare soil materials of Lake Sevan. Izv. Akad. Nauk ArmSSR. Biol. nauki. 13(7):55-60. Bibliog. 9 refs. Summary in Armenian.

90. DOBRIKOV, D. 1960. Useful (soil-forming) activity of earth worms. S. kh. No. 11: 42-43.

91. KOZLOV, K.A. 1960. Influence of electrical sterilization on the microflora of soils in hotbeds. Agrobiologiya. No. 5:703-706. Bibliog. 9 refs.

92. KUZINA, V.P. 1959. Decomposition of the green mass and stubble residues of lupine in sandy soil. Tr. (Novozybkovskaya op. st.). No. 2:279-286.

93. LATYPOVA, R.M. 1960. Comparative activity of catalase and saccharase in peat and certain mineral soils. Doklady Akad. Nauk BSSR. 4(8):357-359. Bibliog. 10 refs.

94. MISHUSTIN, YE.N., and O.I. PUSHKINSKAYA. 1960. Ecogeographical patterns in the distribution of microscopic soil fungi. Izv. Akad. Nauk SSSR. Ser. biol. No. 5:641-660. Bibliog. pp. 657-659.

95. AUGIER, J., and R. MOREAU. 1960. L'activite amylolytique des sols. Methode d'etude et interpretation. Ann. Inst. Pasteur, 99:130-141.

96. CARINI, S., et al. 1959. Studies on the microflora of the soils in the "marcita" of Milan district with special reference to the denitrification process. Ann. Microbiol., 9(1 4):I-II.

97. Consideration sur l'utilisation de l'azote par la prairie temporaire. 1959. Bull. Assoc. Franc., Et. Sol., No. 12:545-556.

98. EBERT, K. 1959. Ueber die Beeinflussung des Wachstums und der Stickstoffbindung von Azotobacter durch Amid-, Ammoniak- und Nitratstickstoff. Ztsch. Pflanzenernähr., Düng., Bodenkunde, 87(132)2:118-134. Bibliog. pp. 133-134.

99. GROSSBARD, E., and D.R. STRANKS. 1959. Translocation of Cobalt^{60} and Gaesium-137 by fungi in agar and soil cultures. —Nature, 184(4683);310-314.

100. HAARLOV, N. 1960. Microarthropods from Dnish soils. Oikos. Suppl., 3, 176 pp.

101. HUG, F., and H. ALI. 1959. Microbiological study of Dacca Soils with seasonal variation. Pakist. J. biol. agric. Sci., 2:47-54.

102. JENSEN, H.L., and P.K. DE ROMA

BHATTACHARYA. 1959. A new nitrogen-fixing bacterium. Nature, No. 4700: 1743.

103. KATO, H. 1959. On streptomyces sendaiensis nsp. producing chloramphenicol. Ecol. Rev., 15(2):79-82.

104. MUELLER, M., et al. 1960. Chromatographische Fraktionierung von Bodenpolysaccariden an Cellulose-Anionen-Austauschers. —14, Mitteilung über Ionen-Austauscher. Z. Pflanzenernähr., Düng., Bodenkunde, 90(135), 1 2, PP. 139-145.

105. RAHMAN, N., and Q. A. AHMED. 1959. Fungi of some Dacca soils. Pakist. J. biol. agric. Sci., 2:1-6.

106. SIMS, C. M., and F. M. COLLINS. 1959. Nitrate production by a thermophilic bacterium. Austral. Agric. Res., 10(6):832-838.

107. Soil sterilization. 1959. Bull. Minestr. Agric. London, 22, 49 pp.

108. STAPLEY, E. O. 1959. Transformation of cysteic acid and taurine by soil microorganisms. Diss. Abstr., 20:1131. Mic. 59-3604, 187 pp.

109. SZEGI, J. 1959. The interrelationships between the Azotobacter and soil actinomyces under laboratory conditions. Agrokemia es Talajtan. 8(4):301-312. Bibliog.

110. ZOETTL, H. 1960. Beziehung zwischen Mineralstickstoff—Anhäufung und Kohlendioxyd—Produktion von Waldhumusproben, im Brutversuch. Z. Pflanzenernähr., Düng., Bodenkunde, 135 (1 2):132-138.

SOIL FERTILITY, FERTILIZERS, AND TILLAGE

111. BABAYAN, G. B. 1960. Soil agricultural chemical characterization of the Mazrina valley. Izv. Akad. Nauk ArmSSR. Biol. nauki. 13(7):47-54. Summary in Armenian.

112. VEPKHADZE, V. M. 1960. Influence of methods of soil tillage on snow melting and the absorption of meltwater. Tr. In-ta lesa (Akad. Nauk GruzSSR). Vol. 9: 69-75. Summary in Georgian.

113. GENKEL', P. A. 1960. The increase of the salt tolerance of plants during the salinization of soils with sulfates. Izv. Akad. Nauk SSSR. Ser. biol. No. 4:550-561. Bibliog. pp. 560-561.

114. GENKEL', P. A., and I. V. TSVETKOVA. 1960. Use of gravel cultures in the study of soil and atmospheric droughts. Fiziologiya rasteniy. 7(5):610-615. Bibliog. 9 refs.

115. GERASIMOV, G. A. 1959. Study of the restoration and increase in soil fertility in Russian agricultural science of the 40's and 50' of the 19th century. Tr. (Permsk. s.-kh. in-t). 17(2):17-34. Bibliog. 10 refs.

116. GORINOV, A. P. 1960. Experimental study of the T. S. Mal'tsev system of soil tillage under conditions of the forest-steppe zone of the Sverdlovsk Oblast'. Tr. Ural'sk. n.-i. in-ta s. kh. Vol. 2:60-64.

117. ZHUKOV, M. S. 1959. Wilting moisture of plants on sandy soils. Tr. (Novozybkovskaya op. st.). No. 2:309-315.

118. ZHUKOV, M. S. 1959. Influence of mineral fertilizers on the change in the acidity of sandy soils. (Problem of the amount of hill fertilization). Ibid. pp. 229-246.

119. ZHUKOV, M. S. 1959. Problem of the increase of the efficiency coefficient of lupine nitrogen on sandy soils. Ibid. pp. 197-208.

120. ZHUKOV, M. S., and A. K. ALEKSEYEVA. 1959. Comparative effectiveness of various forms of potassium fertilizers on sandy soils. Ibid. pp. 287-298. Bibliog. 5 refs.

121. ISTOMINA, R. F. 1960. Change in the fertility of abandoned lands depending on the method of tillage and use. Tr. Ural'sk. n.-i. in-ta s. kh. Vol. 2:34-45. Bibliog. pp. 44-45.

122. KARAVAYEV, V. N. 1960. Agricultural physical and agronomical properties of gray podzolized forest soils and eroded soils of the Central Kama region. Ibid. pp. 96-110. Bibliog. 5 refs.

123. NADEZHDIN, A. M. 1960. Increase of the effectiveness of mineral fertilizers. Zemledeliye, No. 11:51-59.

124. PETUKHOV, M. O. 1959. Fertilizers and the moisture regime of plants. (From the work conducted by the Chair of agricultural chemistry). Tr. Permsk. s.-kh. in-t). 17(2):46-57. Bibliog. p. 57.

125. POTEKHINA, T. V. 1960. Restoration of the fertility of eroded soils. S. kh. Povolzh'ya. No. 10:30-32.

126. RAUDVYALI, E. I. 1960. Agricultural chemical soil service in the Estonian SSR. Zemledeliye, No. 11:62-67.

127. ROGOZHKIN, A. I. 1960. Struggle for the increase of soil fertility. (Bryansk Oblast'). Zemledeliye, No. 9:67-70.

128. RZHEVSKIY, G. K. 1960. Deepening of the plowed layer. S. kh. Uzbekistana. No. 10:18-23.

129. SEMIKHNENKO, P. G., and G. A. AGADZHANYAN. 1960. Characteristics of soil tillage in the piedmont areas of Krasnodar Kray. S. kh. Sev. Kavkaza. No. 10:30-33.

130. SIDOROV, I. S., and V. N. KURANOV. 1960. Influence of plant residues on the fertility of sod-podzolic soils. S. kh. Sev.-Zap.

zony. No. 9:18-21.

131. KHALLIK, O. G. 1960. Use of organic fertilizers and the liming of acid soils in the Estonian SSR. Zemledeliye, No. 11: 60-62.

132. CHIRIKOV, F. V. 1960. Influence of plants on the dynamics of phosphates in soils. Izv. Akad. Nauk SSSR, Ser. biol. No. 5: 707-716. Bibliog. pp. 715-716.

133. A hundred years of successful fertilizer practice. 1959. Frankfurt a. Main, 258 pp.

134. AELBERS, E., and K. HOMBURG. 1959. The inactivation and penetration of simazin into the soil. Meded. Landb. Hogesch. Gent, 24:893-898.

135. DERIMOVA, T., and G. PANTOS. 1959. Mineralization of the slow-acting nitrogen fertilizer "Ureaform" by bacteria isolated from the root zone of corn. Agrokemia es Talajtan, 8(4):313-320. Bibliog.

136. FAICK, R. 1960. Matiere organique et azote des sols de la Moyenne—Guinee et relations avec les rendements des cultures. Compt. rend. Acad. agric. France, 46 (4):152-155.

137. FRANZ, H., and W. LOUB. 1959. Biologische Untersuchungen an Walddüngungsversuchung. Zbl. ges. Forstwesen., 76 (3):129(162.

138. HENDERSON, J. H. M. 1960. Influence of hydrogen ion concentration and autoclaving on gibberellin. Nature, No. 4713:828-829.

139. HINKLE, D. A., and K. J. JAMES. 1959. Cotton fertilizer trials on blackland soils. Arkansas Agric. Expt. Bull., No. 613: 1-10.

140. JAMISON, V. C., and J. E. THORNTON. 1960. Results of deep fertilization and subsoiling on a claypan soil. Agron. J., 52(4):193-195.

141. KAWAI, et al. 1959. Studies on improvement of field soil by short term pasture rotation. —I. Effect of clover rotation on chemical properties of soil. —2. Effect of clover rotation on physical properties of soil. Proc. Crop Sci. Japan, 28(1):88-91.

142. KERNICK, M. D. 1960. The recovery of fertilizer nitrogen from various depths below swards. J. Brit. Grassl. Soc., 15:34-40. Ref. Soils and Fertil., No. 4: 1865.

143. KLOKE, A., and E. PRZEMECK. 1959. Untersuchungen über die P_2O_5—Düngewirkung von Mehrnährstoffdüngern. Landwirtsch. Forsch., 12(1):21-29.

144. MAYR, H. H., and K. KAINDL. 1959. Untersuchungen über die Wirkung organischer Düngemittel auf die Verfügbarkeit der Phosphorsäure. Agrochimica, No. 3: 270-278.

145. TAYLOR, H. M., and H. H. GARDNER. 1960. Use of wax substrates in root penetration studies. Soil Sci. Soc. America Proc., No. 2:79-81.

146. VETTERLEIN, E. 1959. Zur Problematik des Welkebereiches im Boden und seiner Bestimmung. Albrecht-Thaer-Arch., 3: 5-22. Ref.: Soils and Fertil., 1960, No. 2:617.

147. WERMKE, M. 1959. Zur Erfassung der Bodenunterschiede im Feldversuch. Ztschr. Landwirtsch. Fersuchs und Untersuch., 5(3):255-272. Bibliog. 10 refs.

SOIL MELIORATION

148. AGAYEV, B. M. 1960. Melioration of lands with a sodium carbonate type of salinization in the Karabakh steppe. Khlopkovodstvo. No. 11:59-61.

149. ALEKSEYEV, V. I., and N. V. DANIL'CHENKO. 1960. Calculation of the irrigation regime of agricultural crops by the method of the evaporation deficit. Gidrotekhnika i melioratsiya. No. 8:10-15, with maps. Bibliog. 10 refs.

150. BAZHENOV, N. K. 1960. State and outlook for the development of meliorative soil science in Kirgizia. Izv. Kirgiz. filiala Vsesoyuz. geogr. o-va. No. 2:79-84. Bibliog. 18 refs. Summary in Kirgiz.

151. BOGUSHEVSKIY, A. A., YE. P. GALYAMIN, and V. I. MAKAROV. 1960. Role of melioration and melioration investigations in the development of agriculture in the Yakutian ASSR. Tr. Yakut. n.-i. in-ta s. kh. No. 3:80-92. Bibliog. 12 refs.

152. BOGUSHEVSKIY, A. A., YE. P. GALYAMIN, A. A. ZENCHENKO, and V. I. MAKAROV. 1960. Agricultural meliorations in the Yakutian ASSR. Gidrotekhnika i melioratsiya. No. 8:3-9.

153. BELYKH, A. G. 1960. Reclamation of new lands from forests and brush. Edited by A. I. Kuznetsova. Irkutsk. Kn. izd. 92 pp. with illustr.

154. VOLKOVSKIY, P. A., and D. V. OBUKHOV. 1960. Melioration of the Yakhroma River flood plain. Gidrotekhnika i melioratsiya. No. 10:3-15, with maps.

155. DAVYDOV, G. 1960. Changing the genetic horizons of solonetzes in relation to their tillage. S. kh. Sibiri. No. 7:30-32.

156. DENISOV, N. YA., and R. ZH. BALLI. 1960. The "Brail karst" phenomenon during irrigation. Gidrotekhnika i melioratsiya. No. 10:52-53.

157. ZAYDEL'MAN, F. R. 1960. Deep drainage of peat beds. Gidrotekhnika i melioratsiya.

No. 11:25-31. Bibliog. 9 refs.

158. ZNAMENSKIY, I. I. 1960. Organization and mechanization of meliorative hydrological work. 2nd ed. and revised. Izd. M. Sel'khozgiz. 640 pp. with illustr. (Textbook for agricultural institutions of higher learning.)

159. MIKHAYLICHENKO, V. N. 1960. Agricultural meliorative characterization of solonetzes of the Nezhin solonetz station. Tr. In-ta pochvovedeniya Akad. Nauk KazSSR. Vol. 11:127-153. Bibliog. pp. 152-153.

160. PANADIADI, A. D. 1959. Problems and needs of melioration in the non-chernozem belt. Tr. Vsesoyuz. s.-kh. in-ta zaoch. obrazovaniya. No. 2:233-244.

161. RACHINSKIY, A. A. 1960. Present problems of reducing water losses in irrigation systems. Tr. TIIIMSKh (Tashkentsk. in-t inzhenerov irrigatsii i mekhaniz. s. kh.). No. 16:46-55.

162. RUSINOV, I. F. 1960. Influence of melioration on soil fertility. (At the International Conference in Sarvoshe, Hungary.) (June, 1960). Gidrotekhnika i melioratsiya, No. 9:57-59.

163. SELIVANOV, A. P. 1960. Problem of the agricultural melioration of soils in the Far East. Tr. Leningr. politekhn. in-ta. Vol. 208:328-341. Bibliog. 12 refs.

164. Handbook for an agricultural meliorator. 1960. Vilnius, Gospolitnauchizdat. 289 pp. with illustr. Bibliog. 28 refs. (In Lithuanian).

165. SULTANOV, YU. 1960. Dynamics of salinization and the agricultural use of lands in the Kyurkarakashlin area of the Sal' steppe. Sots. s. kh. Azerbaydzhana. No. 8:49-51.

166. UL'YANOV, L. F. 1960. Microestuaries and basin irrigation in the Kuybyshev Oblast'. S. kh. Povolzh'ya. No. 10:33-34.

167. CHJU SHOU-CHUAN. 1960. Saline soils of the Sungari-Nonni valley in Northeastern China and their melioration. Author's summary of his dissertation for a candidate's degree in biological sciences. (Mosk. gos. un-t). Otd. biol. nauk. Moscow. 18 pp.

168. TSINIS, E. A. 1960. Problem of the deep drainage of lowland bogs. (Comments on the article of S. F. Aver'yanov, D. P. Yunevich, and V. M. Ignat'yeva "Deep drainage of lowland bogs" in the journal Gidrotekhnika i melioratsiya, No. 5: 1960.) Gidrotekhnika i melioratsiya, No. 11:31-35. Bibliog. 5 refs.

169. SHEPPEL', P. A. 1960. Use of the hydromechanical method of leveling in the diked areas of the Volga-Akhtoba flood plain. Gidrotekhnika i melioratsiya. No. 8:22-26.

170. EYZEN, I. 1960. Influence of the thermal regime of soil melioration on the growth of cultural plants under conditions of the Estonian SSR. Gidrotekhnika i melioratsiya, No. 10:16-23.

171. BABCOCK, K. L., et al. 1959. A study of the effect of irrigation water composition on soil properties. Hilgardia, 29(3):155-164.

172. DAVIS, E. G., and M. L. GOULD. 1956. Drainage of agricultural land. A bibliography of selected references. Washington, 200 pp. (U. S. Dep. of Agriculture. Miscellaneous publ. No. 713).

173. DURAND, J. H., and C. LUCET. 1958. Transformation chimique de l'eau au cours de l'irrigation par aspersion. Trav. Sec. pedol. argol. bull., No. 4:1-6.

174. FILEP, G. 1959. General characterization of the quality of irrigation waters, groundwaters and aqueous soil extracts. Kiserl. Közlem, 52A:65-72. (In Hungarian).

175. HAAJES, N. H. S. 1959. Land reclamation, defense against the sea and wind erosion in the Netherlands. J. Soil and Water Conserv. India, 7(4-5):16-24.

176. PARKS, W. L., and J. L. KNETSCH. 1960. Utilizing drought days in evaluating irrigation and fertility response studies. Soil Sci. Soc. America Proc., 24(4):289-293.

177. MOUSTAFA, A. E. H. I., and A. I. E. SHABASI. 1959. The effect of gypsum and gypsum plus organic matter on the chemical and physical properties of the black alkaline soils in Egypt. Egypt Minist. Agric. tech. Bull., No. 286:47pp. Ref.: Chem. Abstr., 1960, No. 5:4986.

178. TALATI, N. R., et al. 1959. Importance of soil tests in developing canal irrigation with special reference to Chambal commanded areas of Rajasthan. Indian Soc. Soil Sci., 7(3):177-186.

SOIL EROSION AND ITS CONTROL

179. ALEKPEROV, K. A. 1960. Soil erosion in the Azerbaydzhan SSR and the main methods of its control. Izv. Akad. Nauk Az SSR. Ser. biol. i med. nauk. No. 2:119-122.

180. ANDRIANOVA, K. I. 1960. Methods of controlling wind erosion of soils. Zemledeliye, No. 11:43-50.

181. BABAYEV, N. KH. 1959. Erosion during irrigation and conditions for its prevention. Tr. Kazakhsk. s.-kh. Vol. 6:220-225. Bibliog. 6 refs.

182. BARAYEV, A. I., and A. A. ZAYTSEVA. 1960. Protection of soils in the northern regions of Kazakhstan. Vestn. s.-kh. nauki. No. 10:117-122.

183. Soil erosion control—a necessary part of the system of agriculture. (About the results of the work of the section on soil erosion control at the All-Union Conference of Agricultural Specialists. Leading article). 1960. Lesnoye khoz-vo, No. 8: 1-5.

184. BOCHAROV, A. P. 1960. Problem of the study of the wind erosion of soils. Tr. N.-i. in-ta mekhanizatsii i elektrifikatsii s. kh. (Kazakh. akad. s.-kh. nauk). Vol. 4:301-310. Bibliog. p. 310.

185. BOCHAROV, A., and B. KROT. 1960. Certain data on wind erosion in winter. Dokl. Kazakh. akad. s.-kh. nauk. No. 2:76-78. Summary in Kazakh.

186. Problems of the formation and methods of calculating runoff. 1960. Edited by L. L. Sokolvoskiy and K. P. Voskresenskaya. Tr. Gos. gidrol. in-ta. No. 73. Leningrad, Gidrometeoizdat. 200 pp. with illustr. and maps.

187. DZHUNUSHBAYEV, A. 1960. State and problems of soil erosion investigations in Kirgizia. Izv. Kirgiz. filiala Vsesoyuz. geogr. o-va. No. 2:85-89. Bibliog. 10 refs. Summary in Kirgiz.

188. DOLBIN, A. 1960. Flash floods and methods of controlling them. Vinogradarstvo i sadovodstvo Kryma. No. 8:40.

189. DOSHCHANOV, M. B., and R. G. MURATOVA. 1960. Surface runoff and soil erosion in the Sukoksay basin. Tr. Chatkal'skoy gornomeliorat. op. st. No. 1:26-54.

190. MAKEYEV, O. V. 1960. Problem of drought and soil erosion control and tasks of soil investigations in the Buryat ASSR. Tr. Buryatsk. kompleksnogo n.-i. in-ta (Sibirsk. otdelediye Akad. Nauk SSSR). No. 2:141-152. Bibliog. 17 refs.

191. MAMEDOV, T. M. 1960. Flash floods and forestry measures of controlling them. Moscow—Leningrad, Goslesbumizdat. 60 pp. with illustr. Bibliog. 122 refs.

192. MIRIMANYAN, KH. P. 1960. Let us protect the soil from erosion. Yerevan, Aypetrat. 48 pp. with illustr. (In Armenian).

193. NIKITIN, P. D. 1960. An important condition for the development of agriculture in the southeastern RSFSR. (Water and wind erosion control.) Vestn. s.-kh. nauki. No. 10:123-127.

194. OLIFEROV, A. 1960. Soil erosion in the mountains of Crimea. Vinogradarstvo i sadovodstvo Kryma. No. 8:34-36.

195. PARDZHANADZE, L. K. 1960. Erosion phenomena in the Tsavkisiskhevi basin (Legata-khevi) and methods of controlling them. Tr. In-ta lesa (Akad. Nauk Gruz SSR). Vol. 9:41-51. Bibliog. p. 51. Summary in Georgian.

196. SLASTIKHIN, V. 1960. Polymers in the control of soil erosion. Zemledeliye i zhivotnovodstvo Moldavii. No. 10:30-31.

197. SOBOLEV, S. S. 1960. Control of water and wind erosion in the USSR. Vestn. s.-kh. nauki. No. 10:110-116.

198. TANZYBAYEV, M., and P. FOMIN. 1960. Soil-protective plantings on the eroded lands of the Minusin depression. S. kh. Sibiri. No. 8:17-19.

199. TRUSHIN, V. F. 1960. Fall plowing of soil and erosion. Tr. Sverdl. s.-kh. in-ta. Vol. 7:165-176. Bibliog. 55 refs.

200. TRUSHIN, V. F. Advantages of erosional control of sowing across a slope. Ibid. pp. 177-187. Bibliog. 39 refs.

201. KHARITONOV, G. A. 1959. Problem of stabilizing gulches (erosion). Tr. Ural'sk. lesotekhn. in-ta. No. 16:163-174.

202. CHEREMISINOV, G. A. 1960. Agronomical properties and fertility of eroded soils in the Poltava Oblast'. Nauchn. dokl. vyssh. shkoly. Biol. nauki. No. 3:204-209.

203. CHERNOGOLOVIN, V. P. 1960. Measures for preventing and controlling the wind erosion of soil in the Pavlodar Oblast'. Vestn. s.-kh. nauki. (Alma-Ata). No. 5:16-21. Summary in Kazakh.

204. CHERTOVIKOV, A. 1960. Introduction of the grass-arable system—the most important feature in the control of the wind erosion of soils. S. kh. Kazakhstana, No. 9:36-39.

205. Soil erosion and means for controlling it. 1960. Sb. materialov obl. seminara po zashchite pochv ot erozii v kolkhozakh Ternop. obl. Ternopol'. 57 pp. with illustr. (In Ukrainian).

206. YAKUBOV, T. 1960. Wind erosion of soils and its control. Kolkhoz. proizvodstvo. No. 8:18-20.

207. ANDERSON, H. W. 1960. Research in management of Showpack watersheds for water yield control. J. Forestry, 58(4): 282-284.

208. BASU, J. H., et al. 1959. A right angled "V" notch tank for automatic measurements, of runoff from experimental plots. J. Soil and Water Conservat. India, No. 4-5:8-16.

209. DESHPANDE, P. K. 1959. Role of forests in soil conservation. J. Soil and Water Conservat., 7(2-3):118-121.

210. DUNFORD, E. G. 1960. Watershed management research in the Lake States, Intermountain, and Pacific Northwest Regions. J. Forestry, 58(4):288-290.

211. Effect of intensity of rainfall on the soil and runoff. 1959. J. Indian Soc. Soil Sci.,

7(4):231-238.

212. FRANK, B. 1959. Some aspects of watershed management research in the United States. Mitt. Schweiz. Anstalt forstl. Versuchswesen, 35(1):9-20.

213. JOGLEKAR, D. V. 1959. The "kotar" menace in Gujerat. J. Soil Water Conservat. India, 7(2-3): 121-122.

214. LILLINGER, R. 1959. Neue Wege zur Erosionsverhinderung in den Weinbergen des Landes Rheinland—Pfalz. Wasser und Boden, No. 12:441-443.

215. PALMER, R. S. 1960. Gullies of New England river valleys. J. Soil Water Conservat., 15(4):180-182.

216. REDDY, M. 1959. Sanath Kumar. Role of forests in soil conservation. J. Soil and Water Conservat., India, 7(2-3):116-118.

217. REGE, N. D. 1959. Role of grasses in soil conservation. J. Soil and Water Conservat., India, 7(2-3):77-80.

218. REYNOLDS, H. G. 1960. Watershed management research in Arizona and New Mexico. J. Forestry, 58(4):275-278.

219. SEEDARMA, M. N. 1959. Forest influences and watershed management in Indonesia. Mitt. Schweiz. Anstalt forstl. Versuchswesen, 35(1):111-126.

220. STOREY, H. C. 1960. Watershed research needs and probable future trends in watershed management. J. Forestry, 58(4): 312-316.

221. WAGENHOFF, A. 1959. Vergleich der bisherigen Ergebnisse der Untersuchungen über den Wasserhaushalt und den Bodenabtrag im Harz mit den langfristigen Beobachtungen im Emmental in der Schweiz. Mitt. Schweiz. Anstalt forstl. Versuchswesen, 35(1):127-138.

FOREST SOIL SCIENCE

222. ADRIANOV, S. N. 1960. Configuration of forest shelterbelts in the Altay. Zemledeliye, No. 9:47-52.

223. VOL'FTSUN, I. B. 1960. Characteristics of soil freezing in forest plantations and their effect on surface runoff losses. Tr. Gidrolog. in-ta. No. 81:49-54.

224. GALAYDINA, I. I. 1960. Influence of forest belts of various configurations on the microclimate and yield of agricultural crops. Vestn. s.-kh. nauki (Alma-Ata). No. 6:53-63. Bibliog. 11 refs. Summary in Kazakh.

225. DAUYETAS, M. S. 1960. Afforestation of sands on the seashore of Lithuania. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Litov. s.-kh. akad.). Kaunas. 39 pp.

226. KOLESNIKOV, YE. V. 1960. Study of the growth of the root system of fruit trees using the adsorption method. Izv. Timiryazevskoy s.-kh. akad. No. 4:34-42. Bibliog. 10 refs.

227. NIKITIN, P. D. 1960. Configuration of forest shelterbelts for the Trans-Volga region, Eastern Siberia, and Northern Kazakhstan. Vestn. s.-kh. nauki. No. 8:115-121.

228. ORLOV, A. YA. 1960. Influences of soil factors on the main characteristics of certain types of forests in the southern taiga. Byul. Mosk. o-va ispyt. prirody. Vol. 65, Otd. biol. No. 3:116-131. Bibliog. pp. 130-131.

229. Drainage of forests. 1960. Riga, Latgosizdat. 283 pp. with illustr. Bibliog. pp. 277-280. (By Ya. Odin', K. Bush, Ya. Klyavin', and P. Meyke). (In Latvian).

230. REMEZOV, N. P. 1960. Genesis and forest-growing properties of soils in the Mordov State Reservation. Tr. Mordov. zapovednika. No. 1:25-70. Bibliog. 10 refs.

231. SAMUSENKO, V. F. 1960. Characterization of the composition and properties of forest litters. Sb. rabot po lesnomu khozyaystvu (Vsesoyuz. n.-i. in-t lesovodstva i mekhanizatsii lesn. khoz-va). No. 41:90-98.

232. SCHONNAMSGRUBER, H. 1959. Mineralstoffuntersuchungen an Waldgesellschaften Baden-Württembergs al. Buchen-Eichenwald auf weissem Schlufflehm (Hohenloh plain). Berl. dtsch. bot. Ges., 72(5 6):220-229.

233. WILL, G. M. 1959. Soil-moisture and soil-temperature studies under radiata pine, Whakarew Forest. 1954-1955. New Zealand. Forest Res. Notes, 17:184-193.

GENERAL, HISTORY OF SOIL SCIENCE

234. Materials for the study of soils in the Urals and the Volga region. (Collection of lectures given at the interregional conference on soil science at Ufa, April 6-9, 1959). 1960. Ufa. 298 pp. with illustr. (Bashkir. filial Akad. Nauk SSSR, In-t biol. i Bashkir. otd. Vsesoyuz. o-va pochvovedov).

235. NIKOL'SKIY, N. N. 1959. Soil science. Manual for practical exercises. (Textbook for agricultural institutions of higher learning). Moscow, Sel'khozgiz. 320 pp. with illustr. Bibliog. pp. 312-314.

236. PERSHINA, M. N. 1960. Principal tasks of agronomical soils science in the current seven years. Doklady TSKhA (Mosk. s.-kh. akad.). No. 52:5-14.

237. Soil and yield. 1959. Sb. nauchn. rabot. Latv. n.-i. in-ta zemledeliya. 9. Riga. Izd. Akad. Nauk LatvSSR. 274 pp. with illustr. (In Latvian). Summaries in Russian and English.

238. Soil science. 1960. (Collection of articles under the editorship of A. Mamytov and others). Izv. Akad. Nauk KirgizSSR. Ser. biol. 2(1). Frunze, Izd. Akad. Nauk KirgizSSR. 128 pp. with 1 map sheet.

239. Soils of Bashkiriya and ways of utilizing them rationally. 1959. (Collection of articles under the editorship of S. N. Taychinov). (Bashkir. fil. Akad. Nauk SSSR. In-t biol., Bashkir otd. Vsesoyuz. o-va pochvovedov). No. 2:147. Ufa.

240. Soils and their fertility. 1960. Collection of articles. (Responsible editor, V. N. Simakov). Leningrad, Izd. Leningr. gos. un-ta. 176 pp. with illustr.

241. PRYANISHNIKOV, D. 1959. My memoirs. (Introductory article by A. V. Peterburgskiy). Moscow, Izd. lit. na inostr. yaz. 383 pp. with illustr. (In French).

242. CHAYANOV, S. K. 1959. Reclamation of virgin lands in the semi-desert (of Kazakhstan). Izd. Alma-Ata, Kazgosizdat. 138 pp. with illustr. and 1 map.

243. CHEYCHIS, I. 1960. Dictionary of terms in melioration (Lithuanian-Russian, Russian-Lithuanian). Vilnius. 283 pp.

244. ENGEL'GARDT, A. N. 1959. Selected works. Compiled by A. G. Shestakov. Moscow, Sel'khozgiz. 755 pp. with illustr. maps, and portrait. Bibliog. pp. 737-753.

245. BALMER, J. R. 1959. Le sol. Paris. 160 pp.

246. BONVICINI, M. 1960. Problemi organizzative della sperimentazione agraria italiana. Agricultura Italiana, 60(2):41-54.

247. BRAND, FR. C. 1959. Die Herstellung von Lackfilmprofilen erdfeuchter Böden. Z. Pflanzenernähr., Düng., Bodenkunde, (13)2:123-131.

248. CARPENTER, P. N. 1960. Soil sampling and testing problems and techniques. Florists Exchange, 134(15):15, 35-37.

249. DEMOLON, A. 1960. Dynamique du sol. 5th ed., Paris. 520 pp.

250. DUCHAUFOUR, PH. 1960. Precis de pedologie. Paris, 438 pp.

251. Internationale Bodenkundliche Konferenz der Tschechoslowakischen Akademie der Landwirtschaften. Für die sozialistische Landwirtschaftswissenschaft, 9(1):73-92.

252. HUTCHEON, W. L. 1960. The application of information from soil surveys. Agric. Inst. Rev., Canada. 15(2):51-53.

253. JENNY, H. 1959. Soil as a natural resource. In the book: "Natural resources". New York—London, pp. 184-200.

254. LAND, FORST, GARTEN. 1959. Leipzig 932 pp.

255. RIEHM, H. 1960. Ergebnisse der Bodenuntersuchung im Jahr 1957-58. Landwirtsch. Forsch., Special No. 14(7):78-80.

256. RIPLEY, P. O., and H. J. ATKINSON. 1960. Organization and major lines of soil research. Agric. Inst. Rev., Canada. 15 (2):54-56.

257. SCHEFFER, F., and B. ULRICH. 1960. Lehrbuch der Agrikulturchemie und Bodenkunde.—T. S. Humus und Humusdüngung. No. 1. Morphologie, Biologie. Chemie und Dynamik des Humus. 2nd Ed. Stuttgart, 266 pp.

258. VERMEULEN, F. H. B. 1960. Fehlerquellen bei der Bodenuntersuchung. Landwirtsch. Forsch. Special No. 14:80-85.

259. VERNON, K. C., et al. 1960. Soil and Land-use surveys, No. 9, Grenada, 41 pp. (Regional Res. Cent. ICTA Trinidad). — Ref.: Soils and Fertilizers, 1960, No. 5, 2125.

260. WAGNER, F. 1959. Die technische Durchführung von Feldversuchen. Berlin-Hamburg, 166 pp. Bibliog. pp. 161-162.

AIBS Russian Monograph Translations

The AIBS is in the process of expanding its Russian Translations Program extensively. Funds to subsidize translation and publication of important Russian literature in biology have been obtained from the National Science Foundation, as part of a larger program to encourage the exchange of scientific information between the two countries. The following monographs have been published:

Origins of Angiospermous Plants. *By A. L. Takhtajan*
Edited by G. Ledyard Stebbins. Translated by Olga H. Gankin
68 pp. [13 illustrations] 8½ x 10¾. $3.00, individuals and industrial libraries (U.S. & Canada); $2.00, AIBS members and all other libraries; $.50 additional, foreign.

Essays on the Evolutionary Morphology of Plants. *By A. L. Takhtajan*
Edited by G. Ledyard Stebbins. Translated by Olga H. Gankin
144 pp. [32 illustrations] 8½ x 10¾. $5.00, individuals and industrial libraries (U.S. & Canada); $4.00, AIBS members and all other libraries; $.50, additional, foreign.

Problems in the Classification of Antagonists of Actinomycetes. *By G. F. Gause*
Edited by David Gottlieb. Translated by Fritz Danga
165 pp. [18 illustrations] 7 x 10. $5.00, individuals and industrial libraries (U.S. & Canada); $4.00, AIBS members and all other libraries; $.50, additional, foreign.

Arachnida. Vol. IV, No. 2. Fauna of the U.S.S.R. *By B. I. Pomerantzev*
Edited by George Anastos. Translated by Alena Elbl.
199 pp. [638 illustrations] 7 x 10. $10.00, individuals and industrial libraries (U.S. & Canada); $9.00, AIBS members and all other libraries; $1.00, additional, foreign.

Arachnoidea. Vol. VI, No. 1. Fauna of the U.S.S.R. *By A. A. Zachvatkin*
Translated and edited by A. Ratcliffe and A. M. Hughes
567 pp. [705 illustrations] 7 x 10. $10.00, individuals and industrial libraries; (U.S. & Canada); $9.00, AIBS members and all other libraries; $1.00, additional, foreign.

Marine Biology. Trudy Institute of Oceanology. Vol. XX. *Edited by B. N. Nikitin*
302 pp. [66 illustrations] 8½ x 10¾. $10.00, individuals and industrial libraries; (U.S. & Canada; $7.50, AIBS members and all other libraries; $1.00, additional, foreign.

Plants and Xrays. *By L. P. Breslavets*
Editor of English Edition: Arnold H. Sparrow
115 pp. [26 illustrations] 7 x 10. $5.00, individuals and industrial libraries (U.S. & Canada); $4.00, AIBS members and all other libraries; $.50, additional, foreign.

Wintering of Plants. *By I. M. Vasil'yev*
Editor of English edition: Jacob Levitt.
$9.00, individuals and industrial libraries (U.S. & Canada); $8.00, AIBS members and all other libraries; $.50, additional, foreign.

Monogenetic Trematodes, Their Systematics and Phylogeny. *By Boris E. Bychowsky.*
Editor of English edition: William J. Hargis, Jr.
$10.00, individuals and industrial libraries (U.S. & Canada); $9.00, AIBS members and all other libraries; $.50, additional, foreign.

For orders and a FREE copy of our Publications Catalog listing all AIBS Publications, write to:

AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES
2000 P Street, N.W. Washington 6, D. C.

AGRONOMY SEMINAR
305 DAVENPORT HALL

TRANSLATIONS OF RUSSIAN BIOLOGICAL JOURNALS

The American Institute of Biological Sciences, under a grant from the National Science Foundation, is currently translating and publishing seven Russian research journals in biology.

DOKLADY: BIOLOGICAL SCIENCES SECTION

6 issues per year. First issues published: 1957, Vols. 112-117. Current issues published 1961, Vols. 136-141.

Subscriptions:

$20.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$15.00 per year, AIBS members and all other libraries
$2.50 additional to each price, foreign
$4.00 each, single copies

DOKLADY: BOTANICAL SCIENCES SECTION

6 issues per year. First issues published: 1957, Vols. 112-117. Current issues published 1961, Vols. 136-141.

Subscriptions:

$7.50 per year, individuals and industrial libraries (U.S.A. & Canada
$5.75 per year, AIBS members and all other libraries
$1.50 additional to each price, foreign
$1.50 each, single copies

DOKLADY: BIOCHEMISTRY SECTION

6 issues per year. First issues published: 1957, Vols. 112-117. Current issues published 1961, Vols. 136-141.

Subscriptions:

$15.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$10.00 per year, AIBS members and all other libraries
$3.00 additional to each price, foreign
$4.50 each, single copies

PLANT PHYSIOLOGY • FIIZIOLOGIYA RASTENIY

6 issues per year. First issues published: 1957. Vol. 4, Nos. 1-6. Current issues published: 1961, Vol. 8, Nos. 1-6.

Subscriptions:

$15.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$11.00 per year, AIBS members and all other libraries
$2.00 additional to each price, foreign
$3.00 each, single copies

SOVIET SOIL SCIENCE • POCHVOVEDENIYE

12 issues per year. First issues published: 1958. Current issues published: Jan.-Dec., 1960.

Subscriptions:

$20.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$15.00 per year, AIBS members and all other libraries
$2.50 additional to each price, foreign
$4.00 each, single copies

MICROBIOLOGY • MIKROBIOLOGIYA

6 issues per year. First issues published: 1957, Vol. 26, Nos. 1-6. Current issues published: 1961, Vol. 30, Nos. 1-6.

Subscriptions:

$40.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$20.00 per year, AIBS members and all other libraries
$3.00 additional to each price, foreign
$4.50 each, single copies

ENTOMOLOGICAL REVIEW
ENTOMOLOGICHESKOYE OBOZRENIYE

4 issues per year. First issues published: 1958. Current issues published: 1961, Vol. 40, Nos. 1-4.

Subscriptions:

$25.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$12.00 per year, AIBS members and all other libraries
$3.00 additional to each price, foreign
$7.50 each, single copies

Order from:

AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES
2000 P Street, N.W. Washington 6, D. C.